STATE OF CONNECTICUT.



# SEVENTH ANNUAL REPORT

—OF THE—

# STORRS

# AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

1894



Printed by Order of the General Assembly.

MIDDLETOWN, CONN.:
PELTON & KING, PRINTERS AND BOOKBINDERS.
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The Station is located at Mansfield (P. O. Storrs), as a department of the Storrs Agricultural College. The chemical and other more abstract work is carried out at Wesleyan University, Middletown.

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# OFFICERS OF THE STATION.

## EXECUTIVE COMMITTEE.

T. S. GOLD, West Cornwall, } - - - { *Of the Board of Trustees of*
J. M. HUBBARD, Middletown, } - - - { *Storrs Agricultural College.*

B. F. KOONS, Storrs, - - - - - - *President of the College.*

## TREASURER.

HENRY C. MILES, Milford.

## STATION STAFF.

W. O. ATWATER, Middletown, - - - - - - - *Director.*

C. D. WOODS, Middletown, - - - - - *Vice-Director and Chemist.*

C. S. PHELPS, Storrs, - - - - - - - - *Agriculturist.*

S. H. BUELL, Storrs, - - - - - *Assistant in Farm Experiment.*

# Report of the Executive Committee.

*To His Excellency O. Vincent Coffin,*
*Governor of Connecticut.*

In accordance with the resolution of the General Assembly concerning the Congressional appropriations to Agricultural Experiment Stations, and an Act of the General Assembly, approved March 6th, 1889, relating to the publication of Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Seventh Annual Report of that Station, namely, that for the year 1894.

The Committee refer to the accompanying report of the Treasurer for details of expenditures, and to that of the Director and his associates for the history of the work accomplished, and express their confident belief that the funds have been wisely expended and that the work is such as will result in great benefit to our agricultural interests.

Respectfully submitted,

T. S. GOLD,
J. M. HUBBARD,
B. F. KOONS.
*Executive Committee.*

# Report of the Treasurer

## FOR THE FISCAL YEAR ENDING JUNE 30, 1894.

The following summary of receipts and expenditures is made out in accordance with the form recommended by the Association of American Agricultural Colleges and Experiment Stations, and approved by the United States Treasury Department. The accounts have been duly audited by the Auditors of Public Accounts of the State of Connecticut:

TABULAR STATEMENT OF RECEIPTS AND EXPENDITURES.

| | |
|---|---|
| RECEIPTS. | |
| U. S. Treasury, | $7,500 00 |
| Sale of produce, | 42 63 |
| Analyses, | 86 50 |
| Balance from 1892-93, | 3 76 |
| | $7,632 89 |
| EXPENDITURES. | |
| Salaries, | $4,767 89 |
| Building, | 73 30 |
| Traveling expenses, | 250 64 |
| Executive Committee and Treasurer, | 161 62 |
| Stationery and printing, | 82 18 |
| Postage, telegraph and telephone, | 169 19 |
| Fixtures, permanent, | 177 84 |
| Fixtures, not permanent, | 33 79 |
| Office furniture, | 130 90 |
| Field experiments, | 364 13 |
| Feeding experiments, | 251 49 |
| Team, | 72 67 |
| Student and other labor, | 172 80 |
| Apparatus, immediate, | 238 88 |
| Apparatus, permanent, | 68 52 |
| Chemicals, | 106 37 |
| Fuel, light and power, | 161 47 |
| Hardware and lumber, | 24 61 |
| Freight, cartage and express, | 133 88 |
| Dietary investigations, | 51 59 |
| Bacteriological investigations, | 79 76 |
| Insurance, | 36 75 |
| Incidentals, | 41 21 |
| Balance in Treasury, | 1 41 |
| | $7,632 89 |

HENRY C. MILES, *Treasurer.*

# Report of the Director

## FOR THE YEAR 1894.

The principal lines of inquiry prosecuted during the past year may be concisely stated as follows:

1. Meteorological observations.
2. Field experiments with fertilizers.
3. Experiments on the growth of forage plants.
4. Feeding experiments with sheep.
5. Digestion experiments with sheep.
6. Studies of rations fed to milch cows on dairy farms in Connecticut.
7. Studies of bacteria and their action in the ripening of cream.
8. Analyses of feeding stuffs.
9. Analyses of materials used for the food of man.
10. Investigations of dietaries.
11. Experiments with the bomb calorimeter.
12. Development of a respiration calorimeter.

The larger part of the work done during the year is in continuation of that described in previous reports of the Station.

For an institution with an annual income of only $7,500 per year, which is the amount received by the Storrs Station from public sources, so wide a range of subjects of investigation might seem inexcusable. The justification is found in two facts. One is that several lines of investigation upon the food and nutrition of animals and man are more or less nearly parallel with each other and are so conducted as to form really one department of inquiry. The other is that a considerable part of the work is done with the coöperation and aid of the United States Department of Agriculture, the United States Department of Labor, and Wesleyan University.

W. O. ATWATER,
*Director*.

# BUTTER-FAT vs. SPACE SYSTEM FOR PAYING FOR CREAM AT CREAMERIES.

BY CHAS. D. WOODS.

That the milk from different cows varies materially in its composition has been long understood. It is, however, but a few years since advocates of a deep setting system for cream claimed that when it was raised under uniform conditions, a space of cream always contained the same amount of butter-fat. When this Station undertook, in 1890, a series of feeding experiments with milch cows, a Cooley creamer was purchased and the instructions as to temperature of milk at time of setting, temperature of water, etc., were carefully followed. Analyses of the cream speedily convinced us that the method was far too inaccurate to be relied upon as a measure of the butter-fat production of cows. The range of composition of the cream may be seen from the following tabulation of a few of the results obtained.

*Percentage of Butter-fat in Cooley cream from milk set under uniform conditions of temperature, etc. Each analysis represents 5 days' cream.*

| | Cow No. 1. | Cow No. 2. | Cow No. 3. | Cow No. 4. |
|---|---|---|---|---|
| | % | % | % | % |
| | 20.33 | 21.11 | 21.10 | 22.46 |
| | 20.01 | 21.32 | 21.06 | 23.30 |
| | 19.48 | 21.16 | 20.84 | 22.45 |
| | 18.41 | 20.30 | 19.57 | 20.90 |
| | 18.78 | 21.54 | 19.64 | 20.82 |
| | 18.79 | 21.70 | 19.84 | 20.84 |
| | 20.18 | 20.23 | 20.87 | 21.31 |
| | 19.89 | — | 21.19 | 21.22 |
| Minimum, | 18.41 | 20.23 | 19.57 | 20.82 |
| Maximum, | 20.33 | 21.70 | 21.19 | 23.30 |
| Average, | 19.48 | 21.05 | 20.51 | 21.66 |

The time during which the above samples were taken was about two months. The analyses were made by the gravimetric method. Each of the percentages in the table represents the result of the analyses of five days' cream. It will be observed that there is a range of from 1.5 to 2.5 per cent. in the butter-fat of the cream of the same cow, that of Cow No. 1, for instance, varies from 18.4 to 20.3 per cent. There is also a range of 5 per cent. in the butter-fat of the cream of different cows; from 18.4 in cream from the milk of Cow No. 1 to 23.3 in that of Cow No. 4.

Since these trials we have no doubt as to the unfairness of the space system of paying for cream. If such wide variations in the composition of the cream occurred when every precaution was taken to insure uniformity of conditions, it is evident that the differences would be greater under the usual management of creameries by different patrons. In addition it is possible for dishonest patrons to "manipulate" the cream so as to increase the number of space readings. Moreover, during the winter time many creameries collect the cream only two or three times per week and allow their patrons to draw their own cream and report the number of spaces to the gatherer. The temptations to increase the returns by drawing a few spaces of skim milk with the cream and reporting it all as cream, are frequently too great for human nature to resist.

During the years 1890 to 1893 occasional analyses were made of cream from different creameries and, as was to be expected, a great range in composition of the cream was found. Early in 1894, a creamery in the State asked the assistance of the Station in examining the cream collected on one of its routes. At this time the cream on this route was gathered three times per week, Mondays, Wednesdays and Fridays. For the Monday gathering the patrons were allowed to draw the cream of Friday's and Saturday's setting and report the number of spaces to the gatherer. The Sunday's cream was drawn by the gatherer on Monday morning.

One Monday morning, without previous notice to the patrons, the Friday's and Saturday's cream which had been drawn by the patrons was weighed and samples were taken for analyses. The number of spaces of cream were taken as reported by the patrons. The table on the following page contains the results of the analyses of the cream thus collected.

*Comparison of the Space and Butter-fat Systems of Valuation for one gathering of cream on a suspected route. The cream was drawn by the patron, and "set out" for the gatherer. The number of spaces are as reported by the patrons.*

| Patron's Number. | Spaces of Cream. | Pounds of Cream. | Per Cent. Fat in Cream. | Pounds of Butter-fat.* | Spaces to 1 pound Butter-fat.* | Cost at 3 cts. per Space. | Value at 23.13 cts. per pound for Butter-fat.* | Overpaid. + Underpaid. — | Value per Space when 3 cts. is the average. |
|---|---|---|---|---|---|---|---|---|---|
| 51 | 55 | 32 | 15.6 | 5.0 | 11.0 | $1.65 | $1.16 | +.49 | 2.1c. |
| 52 | 42 | 25 | 17.1 | 4.3 | 9.8 | 1.26 | .99 | +.27 | 2.4 |
| 53 | 42 | 27 | 13.3 | 3.6 | 11.6 | 1.26 | .83 | +.43 | 2.0 |
| 54 | 45 | 31 | 16.4 | 5.1 | 8.8 | 1.35 | 1.18 | +.17 | 2.6 |
| 55 | 40 | 26 | 17.0 | 4.4 | 9.0 | 1.20 | 1.02 | +.18 | 2.6 |
| 56 | 40 | 27 | 11.0 | 3.0 | 13.3 | 1.20 | .69 | +.51 | 1.7 |
| 57 | 19 | 11 | 14.4 | 1.6 | 11.9 | .57 | .37 | +.20 | 2.0 |
| 58 | 15 | 12 | 17.1 | 2.1 | 7.1 | .45 | .49 | —.04 | 3.3 |
| 59 | 30 | 19 | 16.5 | 3.1 | 9.7 | .90 | .72 | +.18 | 2.4 |
| 60 | 191 | 119 | 20.0 | 23.8 | 8.0 | 5.73 | 5.50 | +.23 | 2.9 |
| 61 | 88 | 54 | 19.8 | 10.7 | 8.2 | 2.64 | 2.47 | +.17 | 2.8 |
| 62 | 60 | 56 | 17.0 | 9.5 | 6.3 | 1.80 | 2.20 | —.40 | 3.7 |
| 63 | 17 | 9 | 24.0 | 2.2 | 7.7 | .51 | .51 | — | 3.0 |
| 64 | 63 | 41 | 18.7 | 7.7 | 8.2 | 1.89 | 1.78 | +.11 | 2.8 |
| 65 | 63 | 44 | 19.0 | 8.4 | 7.5 | 1.89 | 1.94 | —.05 | 3.1 |
| 66 | 45 | 53 | 16.8 | 8.9 | 5.1 | 1.35 | 2.06 | —.71 | 4.6 |
| 67 | 92 | 74 | 20.5 | 15.2 | 6.1 | 2.76 | 3.51 | —.75 | 3.8 |
| 68 | 78 | 46 | 19.3 | 8.9 | 8.8 | 2.34 | 2.06 | +.28 | 2.6 |
| 69 | 40 | 31 | 17.7 | 5.5 | 7.3 | 1.20 | 1.27 | —.07 | 3.2 |
| 70 | 55 | 36 | 18.7 | 6.7 | 8.2 | 1.65 | 1.55 | +.10 | 2.8 |
| 71 | 94 | 50 | 17.7 | 8.9 | 10.6 | 2.82 | 2.06 | +.76 | 2.2 |
| 72 | 84 | 53 | 20.6 | 10.9 | 7.7 | 2.52 | 2.52 | — | 3.0 |
| 73 | 38 | 26 | 17.0 | 4.4 | 8.6 | 1.14 | 1.02 | +.12 | 2.7 |
| 74 | 23 | 13 | 18.2 | 2.4 | 9.6 | .69 | .55 | +.14 | 2.4 |
| Total, | 1359 | 915 | — | 166.3 | 8.2 | — | — | — | — |

* One pound of butter-fat is nearly equal to 1.18 lbs. of average butter.

During the month the creamery gathered 62,702 spaces of cream, for which it paid at the rate of 3c. per space. The output for the month was 9,573 pounds of butter. Hence on the average it required 6.55 spaces for each pound of butter. Assuming the butter to be of average composition and to have 85 per cent. of butter-fat, it required on the average 7.71 spaces of cream for each pound of butter-fat. At 3 cents per space the butter-fat would cost on the average 23.13 cents per pound.

That many of the patrons on this route were taking advantage of the way in which the cream was gathered is apparent. It will be observed that it required on the whole route 8.2 spaces of the cream which the patrons drew themselves to make a pound of

butter-fat, while the average for the whole creamery for the month was 7.7 spaces. The number of spaces ranged from 5.1 to 13.3 for one pound of butter-fat. In the case of patron 66, where only 5.1 spaces of cream were required for a pound of butter-fat, it will be noticed that the 45 spaces of cream which were reported as being furnished, weighed 53 pounds, or nearly 1.2 pounds per space instead of the two-thirds of a pound which a space of cream usually weighs. Evidently there was some mistake in the number of spaces which were returned, and as the percentage of butter-fat is rather low, it may be that the patron was intending to return a higher number of spaces, but changed his mind when he saw that samples were being taken. It will also be observed that numbers 62 and 67 have large weights of cream as compared with the number of spaces reported.

The percentages of butter-fat in the cream of this route ranged from 11 to 24 per cent. The average for the route was 16.9 per cent. butter-fat. The fourth column from the last in the table on page 9 shows what was actually paid the patrons for the cream which they drew themselves. The next column gives its value as based upon what the butter-fat cost the creamery on the average for the month, and the next to the last column shows how much each patron was overpaid or underpaid for this lot of cream. With the exception of numbers 62, 66 and 67 above noted, nearly every patron received the full value or more. Probably in these instances, and perhaps in some others, there were mistakes made by the patrons in returning the number of spaces of cream. The last column shows the value per space of the cream which the patrons furnished when the entire cream of the month was paid for at the rate of 3 cents per space. It will be observed that the range is from 1.7 cents per space to 4.6; the three who were the most underpaid per space being Nos. 62, 66 and 67 above noted.

Naturally these figures made considerable impression upon the managers of the creamery, and they desired further tests of the cream furnished them. As no complete observations had been made upon the comparisons of the butter-fat and space systems of paying for cream for long periods of time, such comparisons were made by the Station in this creamery during the entire month of April, 1894. The actual payments of the creamery were made for this month, as for previous ones, by the space system. The table which follows gives the record of the creamery for the month, by both the butter-fat and the space systems. The arrangement is the same as in the preceding table.

*Comparison of the Space and Butter-fat Systems of Valuation in a Creamery for the Month of April, 1894.*

| Patron's Number. | Spaces of Cream. | Pounds of Cream. | Per Cent. Fat in Cream. | Pounds of Butter-fat.* | Spaces to 1 pound Butter-fat.* | Cost at 3 cts. per Space. | Value at 22.92 cts. per pound for Butter-fat.* | Overpaid. + Underpaid. — | Value per Space when 3 cts. is the average. |
|---|---|---|---|---|---|---|---|---|---|
| 101 | 444 | 285 | 20.4 | 58.1 | 7.6 | $13.32 | $13.32 | $ — | 3.0c. |
| 102 | 1112 | 726 | 20.4 | 148.1 | 7.5 | 33.36 | 33.94 | — .58 | 3.1 |
| 103 | 1593 | 1045 | 21.4 | 223.6 | 7.1 | 47.79 | 51.25 | —3.46 | 3.2 |
| 104 | 887 | 578 | 19.7 | 113.9 | 7.8 | 26.61 | 26.11 | + .50 | 2.9 |
| 105 | 1545 | 1026 | 21.0 | 215.5 | 7.2 | 46.35 | 49.39 | —3.04 | 3.2 |
| 106 | 1473 | 961 | 20.3 | 194.9 | 7.6 | 44.19 | 44.67 | — .48 | 3.0 |
| 107 | 1966 | 1264 | 19.4 | 245.2 | 8.0 | 58.98 | 56.20 | +2.78 | 2.9 |
| 108 | 827 | 563 | 20.5 | 115.4 | 7.2 | 24.81 | 26.45 | —1.64 | 3.2 |
| 109 | 620 | 452 | 19.0 | 85.9 | 7.2 | 18.60 | 19.69 | —1.09 | 3.2 |
| 110 | 882 | 599 | 18.8 | 112.6 | 7.8 | 26.46 | 25.81 | + .65 | 2.9 |
| 111 | 309 | 209 | 19.3 | 40.3 | 7.7 | 9.27 | 9.24 | + .03 | 3.0 |
| 112 | 975 | 660 | 17.5 | 115.5 | 8.4 | 29.25 | 26.47 | +2.78 | 2.7 |
| 113 | 337 | 241 | 18.0 | 43.4 | 7.8 | 10.11 | 9.95 | + .16 | 3.0 |
| 114 | 613 | 441 | 16.5 | 72.8 | 8.4 | 18.39 | 16.69 | +1.70 | 2.7 |
| 115 | 604 | 388 | 17.1 | 66.3 | 9.1 | 18.12 | 15.20 | +2.92 | 2.5 |
| 116 | 661 | 445 | 16.8 | 74.8 | 8.8 | 19.83 | 17.14 | +2.69 | 2.6 |
| 117 | 280 | 195 | 17.1 | 33.3 | 8.4 | 8.40 | 7.63 | + .77 | 2.7 |
| 118 | 496 | 320 | 19.2 | 61.4 | 8.1 | 14.88 | 14.07 | + .81 | 2.8 |
| 119 | 283 | 190 | 17.7 | 33.6 | 8.4 | 8.49 | 7.70 | + .79 | 2.8 |
| 120 | 94 | 67 | 16.3 | 10.8 | 8.7 | 2.82 | 2.48 | + .34 | 2.6 |
| 121 | 621 | 411 | 16.6 | 68.2 | 9.1 | 18.63 | 15.63 | +3.00 | 2.5 |
| 122 | 498 | 328 | 21.4 | 70.5 | 7.1 | 14.94 | 16.16 | —1.22 | 3.2 |
| 123 | 729 | 525 | 18.5 | 97.6 | 7.5 | 21.87 | 22.37 | — .50 | 3.1 |
| 124 | 410 | 292 | 19.4 | 56.6 | 7.2 | 12.30 | 12.97 | — .67 | 3.2 |
| 125 | 500 | 352 | 20.3 | 71.5 | 7.0 | 15.00 | 16.39 | —1.39 | 3.3 |
| 126 | 990 | 687 | 19.8 | 136.1 | 7.3 | 29.70 | 31.19 | —1.49 | 3.2 |
| 127 | 1704 | 1201 | 21.1 | 253.0 | 6.7 | 51.12 | 57.99 | —6.87 | 3.4 |
| 128 | 1136 | 775 | 19.9 | 154.1 | 7.4 | 34.08 | 35.31 | —1.23 | 3.1 |
| 129 | 689 | 491 | 20.0 | 98.2 | 7.0 | 20.67 | 22.51 | —1.84 | 3.3 |
| 130 | 248 | 167 | 19.2 | 31.9 | 7.8 | 7.44 | 7.31 | + .13 | 3.0 |
| 131 | 552 | 378 | 21.7 | 81.9 | 6.7 | 16.56 | 18.77 | —2.21 | 3.4 |
| 132 | 774 | 497 | 17.6 | 87.5 | 8.8 | 23.22 | 20.06 | +3.16 | 2.6 |
| 133 | 357 | 223 | 20.4 | 45.5 | 7.8 | 10.71 | 10.43 | + .28 | 2.9 |
| 134 | 551 | 349 | 20.8 | 72.6 | 7.6 | 16.53 | 16.64 | — .11 | 3.0 |
| 135 | 2165 | 1385 | 21.2 | 293.6 | 7.4 | 64.95 | 67.29 | —2.34 | 3.1 |
| 136 | 689 | 414 | 19.9 | 82.4 | 8.4 | 20.67 | 18.89 | +1.78 | 2.7 |
| 137 | 567 | 353 | 16.8 | 59.3 | 9.6 | 17.01 | 13.59 | +3.42 | 2.4 |
| 138 | 1369 | 890 | 20.2 | 179.7 | 7.6 | 41.07 | 41.19 | — .12 | 3.0 |
| 139 | 454 | 316 | 17.0 | 53.7 | 8.5 | 13.62 | 12.31 | +1.31 | 2.7 |
| 140 | 493 | 337 | 19.7 | 66.4 | 7.4 | 14.79 | 15.22 | — .43 | 3.1 |
| 141 | 739 | 561 | 17.7 | 99.3 | 7.4 | 22.17 | 22.76 | — .59 | 3.0 |
| 142 | 290 | 196 | 19.2 | 37.5 | 7.7 | 8.70 | 8.60 | + .10 | 3.0 |
| 143 | 959 | 620 | 20.8 | 129.0 | 7.4 | 28.77 | 29.57 | — .80 | 3.1 |
| 144 | 575 | 368 | 20.1 | 73.9 | 7.8 | 17.25 | 16.94 | + .31 | 2.9 |
| 145 | 1196 | 760 | 21.2 | 161.0 | 7.4 | 35.88 | 36.90 | —1.02 | 3.1 |
| 146 | 477 | 287 | 18.0 | 51.7 | 9.2 | 14.31 | 11.85 | +2.46 | 2.5 |
| 147 | 1201 | 790 | 18.3 | 144.6 | 8.3 | 36.03 | 33.14 | +2.89 | 2.8 |
| 148 | 740 | 492 | 19.4 | 95.5 | 7.7 | 22.20 | 21.89 | + .31 | 3.0 |
| 149 | 472 | 307 | 20.2 | 62.0 | 7.6 | 14.16 | 14.21 | — .05 | 3.0 |

*Comparison of the Space and Butter-fat Systems of Variation in a Creamery for the Month of April, 1894.—Concluded.*

| Patron's Number. | Spaces of Cream. | Pounds of Cream. | Per Cent. Fat in Cream. | Pounds of Butter-fat.* | Spaces to 1 pound Butter-fat.* | Cost at 3 cts. per Space. | Value at 22.92 cts. per pound for Butter-fat.* | Overpaid, + Underpaid, — | Value per Space when 3 cts. is the average. |
|---|---|---|---|---|---|---|---|---|---|
| 150 | 88 | 60 | 16.7 | 10.0 | 8.8 | $2.64 | $2.29 | + .35 | 2.6c. |
| 151 | 162 | 111 | 16.8 | 18.6 | 8.7 | 4.86 | 4.26 | + .60 | 2.6 |
| 152 | 1498 | 976 | 22.3 | 217.7 | 6.9 | 44.94 | 49.90 | —4.96 | 3.3 |
| 153 | 667 | 467 | 19.1 | 89.1 | 7.5 | 20.01 | 20.42 | — .41 | 3.1 |
| 154 | 1152 | 751 | 19.4 | 145.6 | 7.9 | 34.56 | 33.37 | +1.19 | 2.9 |
| 155 | 257 | 160 | 19.9 | 31.9 | 8.1 | 7.71 | 7.31 | + .40 | 2.8 |
| 156 | 370 | 259 | 20.3 | 52.6 | 7.0 | 11.10 | 12.06 | — .96 | 3.3 |
| 157 | 294 | 189 | 21.7 | 40.9 | 7.2 | 8.82 | 9.37 | — .55 | 3.2 |
| 158 | 1334 | 854 | 21.1 | 180.2 | 7.4 | 40.02 | 41.30 | —1.28 | 3.1 |
| 159 | 983 | 699 | 19.5 | 136.3 | 7.2 | 29 49 | 31.24 | —1.75 | 3.2 |
| 160 | 926 | 603 | 20.1 | 121.2 | 7.6 | 27.78 | 27.78 | — | 3.0 |
| 161 | 687 | 504 | 17.4 | 87.6 | 7.8 | 20.61 | 20.07 | + .54 | 2.9 |
| 162 | 317 | 226 | 20.0 | 45.1 | 7.0 | 9.51 | 10.34 | — .83 | 3.3 |
| 163 | 524 | 342 | 17.3 | 59.1 | 8.9 | 15.72 | 13 55 | +2.17 | 2.6 |
| 164 | 567 | 391 | 19.9 | 78.0 | 7.3 | 17.01 | 17.88 | — .87 | 3.2 |
| 165 | 779 | 505 | 22.4 | 113.0 | 6.9 | 23.37 | 25.90 | —2.53 | 3.3 |
| 166 | 1411 | 937 | 20.9 | 185.7 | 7.6 | 42.33 | 42.56 | — .23 | 3.0 |
| 167 | 914 | 593 | 21.3 | 126.3 | 7.2 | 27.42 | 28.95 | —1.53 | 3.2 |
| 168 | 236 | 159 | 19.1 | 30.4 | 7.8 | 7.08 | 6.97 | + .11 | 3.0 |
| 169 | 261 | 170 | 17.1 | 29.1 | 9.0 | 7.83 | 6.67 | +1.16 | 2.6 |
| 170 | 465 | 317 | 21.2 | 67.3 | 6.9 | 13.95 | 15.43 | —1.48 | 3.3 |
| 171 | 565 | 356 | 18.8 | 67.0 | 8.4 | 16.95 | 15.36 | +1.59 | 2.7 |
| 172 | 528 | 358 | 18.8 | 67.3 | 7.8 | 15.84 | 15.42 | + .42 | 2.9 |
| 173 | 347 | 258 | 17.2 | 44.3 | 7.8 | 10.41 | 10.15 | + .26 | 2.9 |
| 174 | 827 | 579 | 17.2 | 99.6 | 8.3 | 24.81 | 22.83 | +1.98 | 2.8 |
| 175 | 861 | 558 | 19.0 | 105.9 | 8.1 | 25.83 | 24.27 | +1.56 | 2.8 |
| 176 | 376 | 285 | 16.5 | 47.0 | 8.0 | 11.28 | 10.77 | + .51 | 2.9 |
| 177 | 273 | 202 | 14.8 | 29.7 | 9.2 | 8.19 | 6.81 | +1.38 | 2.5 |
| 178 | 1196 | 827 | 18.8 | 155.4 | 7.7 | 35.88 | 35.62 | + .26 | 3.0 |
| Total, | 57011 | 38103 | — | 7462.1 | — | $1710.33 | $1710.33 | — | — |

* One pound of butter-fat is nearly equal to 1.18 lbs. average butter.

The total number of spaces collected was 57,011, for which the creamery paid 3 cents per space, or a total of $1,706.07. The cream contained 7,462.1 pounds of butter-fat, from which 9,023.5 pounds of butter were made. The average percentages of the butter-fat in the cream of the 78 patrons varied from 14.8 to 22.4, while the average of all the cream for the month was 19.6 per cent. of butter-fat. On the average, 7.6 spaces were required to make a pound of butter-fat, and the range was from 6.7 spaces to 9.6 spaces per pound of butter-fat. The column headed "cost at 3c. per space," shows what each patron actually received for his cream for the month. What he would have received if he had

been paid by the butter-fat which his cream contained, is shown in the next column, and the amounts underpaid or overpaid are shown in the last column but one. It will be observed that some patrons were very decidedly underpaid, and others were considerably overpaid during the month. One man, No. 127, would have received $6.87 more for his cream if he had been paid by butter-fat, than he actually received by the space system. The last column shows what each patron's cream was worth per space when the creamery was paying 3 cents per space for all the cream used during the month. This ranged from 2.4 to 3.4 cents per space.

As a result of this month's trial, the creamery managers voted unanimously to adopt the butter-fat system of paying for cream, and they have been using this method for a year with satisfactory results.

Partly to satisfy ourselves that the results obtained at this particular creamery were not peculiar to it, and partly to show the managers of another creamery the unfairness of the space system, a week's test was made at the latter. The results are given in the table on the next page.

The total weight of the 8,814 spaces of cream was 6,661.7 pounds. The average percentage of butter-fat in the cream was 18.1; the lowest percentage of butter-fat was 14, and the highest, 21.75 per cent. The arrangement of the table is the same as the preceding. The fourth column from the last, headed "cost at 3c. per space," shows what was actually paid the patrons, the next column the amounts which they would have received if they had been paid by butter-fat system. The last column but one shows how much each patron was overpaid or underpaid during the week. The value per space of the cream on the butter fat basis is shown in the last column; it ranged from 2.6 cents to 3.6 cents per space when the average price paid was 3 cents per space. This means that the patrons numbered 16, 19, 32 and 39 each received $3.00 for each hundred spaces of cream which they furnished, when in reality the cream was worth only $2.60 per hundred; and that at the same time the patrons numbered 5 and 40 were furnishing cream worth $3.50 per hundred spaces, for which they received only $3.00 per hundred. In other words, patrons 5 and 40 were each giving 50 cents per hundred spaces to their neighbors who were producing poorer cream.

*Comparison of the Space and Butter-fat Systems of Valuation in a Creamery for one week in May, 1894.*

| Patron's Number. | Spaces of Cream. | Pounds of Cream. | Per Cent. Fat in Cream. | Pounds of Butter-fat.* | Spaces to 1 pound Butter-fat.* | Cost at 3 cts. per Space. | Value at 22 cents per pound for Butter-fat.* | Overpaid. + Underpaid. — | Value per Space when 3 cts. is the average. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 510 | 324.1 | 20 | 64.8 | 7.9 | $15.30 | $14.23 | +1.07 | 2.8c. |
| 2 | 329 | 245.9 | 17 | 41.7 | 7.9 | 9.87 | 9.16 | + .71 | 2.8 |
| 3 | 450 | 331.8 | 18 | 59.7 | 7.5 | 13.50 | 13.10 | + .40 | 2.9 |
| 4 | 164 | 130.1 | 16.5 | 21.5 | 7.6 | 4.92 | 4.72 | + .20 | 2.9 |
| 5 | 58 | 52.5 | 17.5 | 9.2 | 6.3 | 1.74 | 2.02 | — .28 | 3.5 |
| 6 | 438 | 315.6 | 19.5 | 61.5 | 7.1 | 13.14 | 13.50 | — .36 | 3.1 |
| 7 | 105 | 72.9 | 21.75 | 15.9 | 6.6 | 3.15 | 3.49 | — .34 | 3.3 |
| 8 | 129 | 83.9 | 20.5 | 17.2 | 7.5 | 3.87 | 3.77 | + .10 | 2.9 |
| 9 | 254 | 207.8 | 15.5 | 32.2 | 7.9 | 7.62 | 7.07 | + .55 | 2.8 |
| 10 | 163 | 123.4 | 16.25 | 20.0 | 8.1 | 4.89 | 4.39 | + .50 | 2.7 |
| 11 | 148 | 125.2 | 17.5 | 21.6 | 6.9 | 4.44 | 4.74 | — .30 | 3.2 |
| 12 | 231 | 171.9 | 20 | 34.4 | 6.7 | 6.93 | 7.56 | — .63 | 3.3 |
| 13 | 151 | 132.3 | 19 | 25.1 | 6.0 | 4.53 | 5.52 | — .99 | 3.6 |
| 14 | 158 | 123.2 | 17.5 | 21.6 | 7.3 | 4.74 | 4.74 | — | 3.0 |
| 15 | 198 | 163.2 | 17.5 | 28.6 | 6.9 | 5.94 | 6.28 | — .34 | 3.2 |
| 16 | 48 | 39 9 | 14 | 5.6 | 8.6 | 1.44 | 1.23 | + .21 | 2.6 |
| 17 | 105 | 95.7 | 14.75 | 14.1 | 7.4 | 3.15 | 3.09 | + .06 | 3.0 |
| 18 | 95 | 92.5 | 15.5 | 14.3 | 6.6 | 2.85 | 3.14 | — .29 | 3.3 |
| 19 | 240 | 189.4 | 15 | 28.4 | 8.5 | 7.20 | 6.24 | + .96 | 2.6 |
| 20 | 201 | 179.3 | 16.25 | 29.1 | 6.9 | 6.03 | 6.39 | — .36 | 3.2 |
| 21 | 45 | 40.0 | 17 | 6.8 | 6.6 | 1.35 | 1.50 | — .15 | 3.3 |
| 22 | 196 | 160.8 | 16.75 | 26.9 | 7.3 | 5.88 | 5.91 | — .03 | 3.0 |
| 23 | 151 | 131.5 | 14 | 18.4 | 8.2 | 4.53 | 4.04 | + .49 | 2.7 |
| 24 | 214 | 174.8 | 19 | 33.2 | 6.4 | 6.42 | 7.29 | — .87 | 3.4 |
| 25 | 330 | 254.7 | 18.25 | 46.5 | 7.1 | 9.90 | 10.21 | — .31 | 3.1 |
| 26 | 688 | 454.8 | 19 | 86.4 | 7.9 | 20.64 | 18.75 | +1.89 | 2.7 |
| 27 | 104 | 75.3 | 24 | 18.1 | 5.7 | 3.12 | 3.93 | — .81 | 3.7 |
| 28 | 406 | 267.7 | 20 | 53.5 | 7.6 | 12.18 | 11.61 | + .57 | 2.9 |
| 29 | 158 | 141.0 | 17 | 24.0 | 6.6 | 4.74 | 5.21 | — .47 | 3.3 |
| 30 | 179 | 119.6 | 20.25 | 24.2 | 7.4 | 5.37 | 5.25 | + .12 | 2.9 |
| 31 | 170 | 131.9 | 16.25 | 21.4 | 7.9 | 5.10 | 4.64 | + .46 | 2.7 |
| 32 | 83 | 66.1 | 15.25 | 10.1 | 8.2 | 2.49 | 2.19 | + .30 | 2.6 |
| 33 | 48 | 37.8 | 17 | 6.4 | 7.5 | 1.44 | 1.39 | + .03 | 2.9 |
| 34 | 405 | 317.7 | 17.50 | 54.8 | 7.4 | 12.15 | 11.94 | + .21 | 2.9 |
| 35 | 68 | 47.7 | 21.0 | 10.0 | 6.8 | 2.04 | 2.17 | — .13 | 3.2 |
| 36 | 180 | 124.4 | 19 | 23.6 | 7.6 | 5.40 | 5.12 | + .28 | 2.9 |
| 37 | 158 | 127.4 | 18.5 | 23.6 | 6.7 | 4.74 | 5.12 | — .38 | 3.2 |
| 38 | 58 | 45.5 | 19 5 | 8.9 | 6.5 | 1.74 | 1.93 | — .19 | 3.3 |
| 39 | 292 | 195.4 | 18.75 | 36.6 | 8.0 | 8.76 | 7.94 | + .82 | 2.6 |
| 40 | 136 | 105.3 | 20.75 | 21.8 | 6.2 | 4.08 | 4.76 | — .68 | 3.5 |
| 41 | 433 | 329.1 | 20.50 | 67.5 | 6.4 | 12.99 | 14.71 | —1.72 | 3.4 |
| 42 | 137 | 112.8 | 18.0 | 20.3 | 6.7 | 4.11 | 4.43 | — .32 | 3.2 |
| Total, | 8814 | 6661.5 | — | 1209.5 | — | $264.42 | $264.42 | — | — |

* One pound of butter-fat is nearly equal to 1.18 lbs. of average butter.

## BUTTER-FAT METHOD OF PAYING FOR CREAM.

This method is fully described in Bulletin No. 119 of the Connecticut Experiment Station, pages 5-15; and in the Annual Report of that Station for 1894, pages 217-231. It may be briefly summarized as follows:

*Apparatus needed.*—A cream-gatherer's pail, spring balance weighing to about 60 pounds, sampling tube, set of collecting bottles for the dairy sample (these are best made of metal), and a set of larger bottles for the composite sample are needed for each route. The analysis of the cream is best made by the Babcock "apparatus for determining fat in milk and in cream."* This is furnished complete in various sizes, for power or hand use, by all dealers in creamery supplies. The total cost of apparatus needed to change from the space system to the butter-fat method of paying for cream will be from $50 or $75, or upwards, in accordance with the number of patrons, number of routes, and other conditions of the creamery.

*Sampling and collecting the cream.*—Each patron should be designated by a number, which number should be used on the sample bottle and in the gatherer's book. The patrons should be requested to draw their cream before the gatherer arrives. Each patron's cream should be thoroughly mixed by pouring at least twice from one vessel to another, or by the thorough use of an "agitator," before the sample is drawn. After the cream is thoroughly mixed and poured into the gatherer's pail, the stop-cock of the sampling tube is opened and the tube is slowly lowered into the pail of cream. It is then raised so as to allow the cream to run out and thus rinse the tube before taking the sample. The tube is again slowly lowered into the cream, the stop-cock is closed, the tube raised carefully, allowed to drain for a few seconds, wiped with a cloth and held over the sample bottle, the stop-cock is opened and the cream sample allowed to run into the bottle. Care in sampling is of the utmost importance. After taking the sample the cream is weighed and its weight recorded in the same way that spaces are recorded in the space system. At the creamery the small sample is poured into the larger "composite bottle" which bears the patron's number and to which a very little corrosive sublimate† or bi-chromate of potash has been added as a preservative.

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* For description of this apparatus, see Wisconsin Experiment Station Report, 1890, pages 98-119, and the publications of the Connecticut Station above referred to.

† This is a very active poison and should be carefully kept and handled. For keeping cream not more than a week the bi-chromate of potash answers equally well and is not a dangerous poison. Its use is, therefore, to be preferred.

*Analysis of the cream. Book-keeping.*—After several collections have been made the composite samples are analyzed and the percentages of butter-fat in the cream are determined and recorded. The analyses can be made three or four times during the month. In practice in most creameries they are made each week or four times during the month.

The weight of the cream collected multiplied by the percentage of butter-fat which it contained gives the weight of butter-fat. The amount of money to be paid the patrons divided by the total number of pounds of butter-fat collected gives the price per pound for the month. The number of pounds of butter-fat furnished by each patron multiplied by the price paid per pound gives, as in the space system, the amount due each patron.

### WHY THE BUTTER-FAT SYSTEM FOR PAYING FOR CREAM IS PREFERABLE TO THE SPACE SYSTEM.

The chief, and it seems to us fatal, objection to the use of the space system as the basis of payment for cream furnished by the patrons of creameries is its manifest unfairness and injustice. As is shown in both of the cases of the creameries examined as above, the cream furnished by patrons varies greatly in quality. One patron receives $3.00 per hundred spaces for cream which is worth only $2.50 at the average rate at which the creamery is paying, while another person receives only $3.00 for the same amount of cream which is worth $3.50. The butter-fat system involves somewhat more labor at the creamery, but all creameries which have adopted the butter-fat method for payment, so far as we know, are persuaded that this extra labor is amply repaid in the greater fairness and satisfaction to patrons as well as by the greater economy of the butter production. Under the space system, creameries find it necessary to make occasional churnings of the cream of individual patrons, and in some instances, at least, the time consumed for these occasional and imperfect tests is greater than is needed for the systematic and accurate tests by the butter-fat method.

If creamery managers will do business upon a thoroughly square basis there is no question that some other method than the space system must be adopted. There is to-day no better and fairer method known than the system of payment for cream by its butter-fat content. Believing this to be a very important matter for the farming community in general, the Station is prepared to assist any creamery that wishes to adopt the butter-fat method.

# RESULTS OF ANALYSES OF FODDERS AND FEEDING STUFFS.

BY CHAS. D. WOODS.

In connection with the work of the Station, analyses of the following miscellaneous feeding stuffs have been made by the Station chemists. For the most part the analyses were made in connection with feeding experiments or experiments upon the growth of plants. In no case were they undertaken merely to increase the amount of this class of data. The methods of analyses recommended by the Association of Official Agricultural Chemists were employed.

The results of the analyses as calculated to water content at harvest or at the time of analyses are given in table 1, page 21, which follows the description of samples. In this table the materials are grouped somewhat according to their water content at time of taking samples, as follows: Green fodders; silage; cured hay and fodder; grain; and milling products. This order is also observed in the descriptions of samples.

The results calculated to water-free substance (dry matter) as the basis are given in table 2, page 23.

The fuel value of a pound of each of the feeding stuffs as given in the tables was obtained by multiplying the number of hundredths of a pound of protein and of carbohydrates by 18.6, and the number of hundredths of a pound of fat by 42.2, and taking the sum of these three products as the number of calories of potential energy in the materials.*

## DESCRIPTION OF SAMPLES.

In the description of samples the order of arrangement is the same as in the tables.

### GREEN FODDERS.

1359–1362, *Orchard Grass (Dactylis glomerata).*—Grown in the grass garden of the Station in 1894. The samples were all taken June 18th, at which time the

* See paper on Fuel Value of Feeding Stuffs in Report of this Station for 1890, pp. 174–181.

seed was just beginning to form. No. 1359 was grown without the use of fertilizers. Growth light and spindly; pale colored. No. 1360 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Growth much resembled that of 1359. No. 1361 was grown on a plot to which mixed minerals were applied as in 1360 and had in addition 160 pounds of nitrate of soda per acre. The grass was of good color and the growth was much heavier than that of 1359 and 1360. No. 1362 was grown on a plot to which mixed minerals were applied as in 1360 and had in addition 480 pounds of nitrate of soda. Heavy, dense growth of good color.

1351–1354, *Tall Meadow Fescue Grass (Festuca elatior)*.—Grown in the grass garden of the Station in 1894. The samples were taken June 27th, at which time seed was beginning to form. No. 1351 was from a plot without fertilizers. Light, spindly growth of pale color. No. 1352 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Growth resembled that of 1351. No. 1353 was grown on a plot to which mixed minerals were applied as in 1352 and had in addition 160 pounds of nitrate of soda per acre. Quite heavy growth of fair color. The bottom growth was quite thick. No. 1354 was grown on a plot to which mixed minerals were applied as in 1352 and had in addition 480 pounds of nitrate of soda. Heavy, dense growth of dark green color. Under growth thick.

1347–1350, *Tall Meadow Oat Grass (Avena elatior)*.—Grown in Station grass garden in 1894. Samples were taken June 18th, at which time seed was beginning to form. No. 1347 was grown without the use of fertilizers. Light, spindly growth of pale color. No. 1348 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Growth resembled 1347 except grass was a little more mature. No. 1349 was grown on a plot to which mixed minerals were applied as in 1348 and had in addition 160 pounds of nitrate of soda per acre. Fair growth of good color. No. 1350 was grown on a plot to which mixed minerals were applied as in 1348 and had in addition 480 pounds of nitrate of soda. Thick, heavy growth of good color.

1355–1358, *Timothy (Phleum pratense)*.—Grown in the Station grass garden in 1894. The samples were taken July 3, 1894, at which time the grass was just past full bloom. No. 1355 was grown without the use of fertilizers. Light, thin growth. No. 1356 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. Growth much like that of 1355. No. 1357 was grown on a plot to which mixed minerals were applied as in 1356 and had in addition 160 pounds of nitrate of soda per acre. Quite heavy growth. No. 1358 was grown on a plot to which mixed minerals were applied as in 1356 and had in addition 480 pounds of nitrate of soda. Heavy, dense growth.

1370, 1372, 1374, 1376, *Barley Fodder*.—As used in digestion experiments.* The samples were taken from the field from October 8th to October 15th. No.

* See article on Digestion Experiments beyond in this Report.

1370, cut October 8, 1894, nearly grown, in early bloom; 1372, cut October 11th, in bloom, some seeding; 1374, cut October 13th, early seeding; 1376, cut October 15th, seeding but still succulent.

1369, 1371, 1373, 1375, *Barley and Pea Fodder*, as used in digestion experiments.* The samples were taken from the field from October 8th to October 15th. No. 1369, cut October 8th, barley nearly grown, in early bloom; peas beginning to blossom. No. 1371, cut October 11th, barley nearly grown, in bloom and beginning to seed; peas have many blossoms. No. 1373, cut October 13th, barley early seeding; peas full grown and full bloom. No. 1375, cut October 15th, barley early seeding, still succulent; peas mostly still green and in bloom.

1366–1368, *Cow Pea Vines (Dolichos sinensis).*—Good growth on all plots. Samples taken September 18, 1894. No. 1366 was from a plot to which there were applied dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1367 was grown on a plot to which mixed minerals were applied as in 1366 and had in addition 160 pounds of nitrate of soda per acre. No. 1368 was grown on a plot to which mixed minerals were applied as in 1366 and had in addition 480 pounds of nitrate of soda per acre.

1341–1343, *Scarlet Clover (Trifolium incarnatum)*, used in digestion experiments.* Samples were taken May 26th to June 2d.

ENSILAGE.

1262, *Corn Ensilage.*—Samples were taken in connection with milch cow ration No. 18.

CURED FODDERS AND HAYS.

1274, *Fodder.*—The fodder consisted of about 500 pounds of oat straw and 75 pounds bog hay, mixed as it was run through the cutter. Sample was taken of each separately and combined in the above proportions at the laboratory. Taken in connection with milch cow ration No. 20.

1269, 1279 and 1289, *Corn Stover.*—Samples taken in connection with milch cow rations Nos. 19, 22 and 24 respectively.

1276 and 1278, *Oat Hay.*—Samples taken in connection with milch cow rations Nos. 20 and 22 respectively.

1297, *Timothy Hay. Early cut.*—Samples taken in connection with milch cow ration No. 26.

1325–1328, *Early Cut Hay. Mixed grasses.*—Sample taken in connection with digestion experiments Nos. 1 to 4. (See article beyond on digestion experiments).

1263, 1264, 1268, 1277 and 1290, *Hay from Mixed Grasses.*—Nos. 1264 and 1290 were timothy and red-top hay, about three-fourths timothy and one-fourth red-top. Samples were taken in connection with milch cow rations Nos. 18 and 24. Nos. 1263, 1268 and 1277 were ordinary hay from mixed grasses. Samples were taken in connection with milch cow rations Nos. 18, 19 and 22.

1288, *Clover Hay.*—Samples were taken in connection with milch cow ration No. 24. The hay was about three-fourths clover and one-fourth mixed grasses.

*See article on Digestion Experiments beyond in this Report.

SEEDS.

1363–1365, *Soy Beans (Soja hispida).*—Grown by the Station in 1892. No. 1363 was grown upon a plot which received dissolved bone-black at the rate of 320 pounds per acre and muriate of potash at the rate of 160 pounds. No. 1364 was grown upon a plot which received, in addition to the same mixed minerals as 1109, nitrate of soda at the rate of 160 pounds per acre. No. 1111 was from a plot which received, in addition to the same mixed minerals as 1109, 480 pounds of nitrate of soda per acre. No. 1341, cut May 26th, at which time the clover was not quite in full bloom; 1342, cut May 28th, in full bloom; 1343, cut June 2d, a little past full bloom, lower half of heads beginning to seed.

1303, 1340, *Oats and Peas.*—These were grown by the Station in 1893 for the seed. They were used in digestion experiments, and for further description of samples see article on digestion experiments beyond.

MILLING AND BY-PRODUCTS.

1265, 1300 and 1305, *Corn Meal.*—From western grown corn. No. 1265 was used in milch cow ration No. 18; 1300 and 1305 in digestion experiments.

1273, 1281, 1283, 1287 and 1294, *Corn and Cob Meal.*—All Connecticut grown. Samples taken in connection with milch cow rations Nos. 20, 22, 23, 24 and 25 respectively.

1272, *Cob and Rye Meal.*—Corn on the cob and rye, ground together in the proportions of 14 bushels of corn on the ear and 6 bushels of rye. Samples taken in connection with milch cow ration No. 19.

1266, 1271, 1275, 1280 and 1284, *Wheat Bran.*—Samples taken in connection with milch cow rations Nos. 18, 19, 20, 22 and 23. No. 1275 is a winter wheat bran.

1299, *Wheat Middlings.*—Samples taken in connection with milch cow ration No. 26.

1291, *Linseed Meal.*—Sample taken in connection with milch cow ration No. 25.

1302, *Linseed Mixture.*—Used in digestion experiments (see beyond). The mixture consisted of three parts old process linseed meal and one part corn meal. The corn meal was from the same lot as samples No. 1300 and 1305 above.

1282, 1286, 1293, *Chicago Gluten Meal.*—Samples taken in connection with milch cow rations Nos. 23, 24 and 25 respectively.

1270, *Cream Gluten Meal.*—Samples taken in connection with milch cow ration No. 19.

1298, *Peoria Gluten Feed.*—Samples taken in connection with milch cow ration No. 26.

1296, *Sheep Feed.*—The grain and ensilage used by Mr. Chas. Lyman of Middlefield for fattening sheep in the winter of 1893–94. The mixture was as follows: Corn ensilage 2,400 pounds, whole corn 500 pounds, pea meal 1,000 pounds, and wheat middlings 800 pounds. This, together with about 400 pounds of hay a day, made a day's ration for 1,300 sheep.

TABLE I.

*Proximate Composition of Fodders and Feeding Stuffs. Results of Analyses Herewith Reported, Calculated to Water Content at Time of Taking Sample.*

| Lab. No. | KIND.* | Water. | Protein. | Fat. | Nit.-free Ext. | Fiber. | Ash. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|
| | *Green Fodders.* | % | % | % | % | % | % | Calories per lb. |
| 1359 | Orchard grass, - - | 63.83 | 2.73 | 1.10 | 16.14 | 13.38 | 2.82 | 645 |
| 1360 | Orchard grass, - - | 65.50 | 2.47 | .98 | 14.91 | 13.16 | 2.98 | 605 |
| 1361 | Orchard grass, - - | 66.97 | 2.61 | 1.17 | 14.43 | 11.98 | 2.84 | 585 |
| 1362 | Orchard grass, - - | 71.93 | 2.98 | .97 | 11.68 | 10.17 | 2.27 | 500 |
| | Average, - - - - | **67.06** | **2.69** | **1.06** | **14.29** | **12.17** | **2.73** | **570** |
| 1351 | Tall meadow fescue grass, | 68.63 | 1.86 | .77 | 12.61 | 13.93 | 2.20 | 555 |
| 1352 | Tall meadow fescue grass, | 67.72 | 1.93 | .77 | 16.22 | 11.02 | 2.34 | 570 |
| 1353 | Tall meadow fescue grass, | 72.43 | 1.90 | .75 | 12.65 | 10.24 | 2.03 | 490 |
| 1354 | Tall meadow fescue grass, | 76.85 | 2.22 | .73 | 9.18 | 9.04 | 1.98 | 410 |
| | Average, - - - - | **71.41** | **1.98** | **.75** | **12.66** | **11.06** | **2.14** | **505** |
| 1347 | Tall meadow oat grass, - | 66.40 | 2.68 | 1.02 | 15.13 | 12.34 | 2.43 | 600 |
| 1348 | Tall meadow oat grass, - | 67.31 | 2.47 | 1.04 | 14.41 | 12.24 | 2.53 | 585 |
| 1349 | Tall meadow oat grass, - | 69.18 | 2.67 | .98 | 14.04 | 11.07 | 2.06 | 555 |
| 1350 | Tall meadow oat grass, - | 68.99 | 3.57 | 1.05 | 13.20 | 11.07 | 2.12 | 560 |
| | Average, - - - - | **67.97** | **2.85** | **1.02** | **14.20** | **11.68** | **2.28** | **575** |
| 1355 | Timothy, - - - - | 66.65 | 3.86 | 1.06 | 14.49 | 12.07 | 1.87 | 605 |
| 1356 | Timothy, - - - - | 67.13 | 2.23 | .87 | 17.28 | 10.42 | 2.07 | 590 |
| 1357 | Timothy, - - - - | 67.60 | 6.31 | 1.03 | 10.92 | 12.29 | 1.85 | 590 |
| 1358 | Timothy, - - - - | 69.28 | 2.40 | 1.11 | 14.02 | 11.50 | 1.69 | 565 |
| | Average, - - - - | **67.66** | **3.70** | **1.02** | **14.18** | **11.57** | **1.87** | **585** |
| 1370 | Barley, - - - - - | 78.05 | 3.52 | .87 | 9.80 | 5.84 | 1.92 | 395 |
| 1372 | Barley, - - - - - | 76.70 | 3.56 | .90 | 9.11 | 7.48 | 2.25 | 413 |
| 1374 | Barley, - - - - - | 76.57 | 3.68 | .91 | 10.32 | 6.37 | 2.15 | 420 |
| 1376 | Barley, - - - - - | 75.31 | 3.50 | .91 | 11.96 | 6.52 | 1.80 | 445 |
| | Average, - - - - | **76.66** | **3.56** | **.90** | **10.30** | **6.55** | **2.03** | **420** |
| 1369 | Barley and peas, - - | 81.77 | 3.80 | .81 | 7.33 | 4.69 | 1.60 | 330 |
| 1371 | Barley and peas, - - | 80.62 | 3.71 | .77 | 7.98 | 5.10 | 1.82 | 345 |
| 1373 | Barley and peas, - - | 79.63 | 4.22 | .98 | 8.64 | 4.95 | 1.58 | 370 |
| 1375 | Barley and peas, - - | 79.89 | 3.91 | .71 | 8.72 | 5.22 | 1.55 | 360 |
| | Average, - - - - | **80.47** | **3.91** | **.81** | **8.16** | **4.99** | **1.66** | **351** |
| 1366 | Cow pea vines, - - | 85.55 | 2.72 | .55 | 5.94 | 3.38 | 1.86 | 250 |
| 1367 | Cow pea vines, - - | 84.00 | 2.84 | .68 | 7.13 | 3.35 | 2.00 | 270 |
| 1368 | Cow pea vines, - - | 84.99 | 3.01 | .61 | 6.44 | 3.04 | 1.91 | 255 |
| | Average, - - - - | **84.85** | **2.86** | **.61** | **6.50** | **3.26** | **1.92** | **260** |
| 1341 | Scarlet clover, - - | 87.31 | 2.48 | .64 | 5.00 | 3.24 | 1.33 | 225 |
| 1342 | Scarlet clover, - - | 83.89 | 2.73 | .65 | 6.96 | 4.37 | 1.40 | 285 |
| 1343 | Scarlet clover, - - | 84.45 | 2.91 | .72 | 6.16 | 4.20 | 1.56 | 275 |
| | Average, - - - - | **85.22** | **2.71** | **.67** | **6.04** | **3.93** | **1.43** | **260** |
| | *Ensilage.* | | | | | | | |
| 1262 | Corn ensilage, - - | 69.32 | 2.84 | 1.29 | 19.75 | 5.18 | 1.62 | 570 |
| | *Cured Hay and Fodders.* | | | | | | | |
| 1274 | Fodder, mostly stover, - | 27.05 | 5.54 | 2.09 | 34.90 | 25.85 | 4.57 | 13.20 |

* For description of samples, see pages 17–20.

TABLE I.—*(Continued.)*

| Lab. No. | KIND.* | Water. | Protein. | Fat. | Nit.-free Ext. | Fiber. | Ash. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|
| | *Cured Hay and Fodders. (Continued.)* | % | % | % | % | % | % | Calories per lb. |
| 1269 | Corn stover, - - | 14.05 | 5.80 | 2.22 | 44.16 | 28.73 | 5.04 | 1555 |
| 1279 | Corn stover, - - | 7.49 | 9.88 | 2.30 | 51.56 | 22.11 | 6.66 | 1650 |
| 1289 | Corn stover, - - | 15.94 | 7.80 | 1.86 | 41.55 | 26.96 | 5.89 | 1495 |
| | Average, - - | **12.49** | **7.83** | **2.13** | **45.77** | **25.93** | **5.85** | **1565** |
| 1276 | Oat hay, - - | 16.23 | 7.62 | 3.36 | 42.20 | 25.03 | 5.56 | 1535 |
| 1278 | Oat hay, - - | 6.21 | 10.75 | 3.48 | 43.16 | 30.97 | 5.43 | 1725 |
| | Average, - - | **11.22** | **9.18** | **3.42** | **42.68** | **28.00** | **5.50** | **1630** |
| 1297 | Timothy hay, - | 10.58 | 7.33 | 2.83 | 45.23 | 28.45 | 5.58 | 1650 |
| 1325 | Hay, early cut, - | 8.78 | 10.94 | 3.69 | 40.27 | 31.11 | 5.21 | 1685 |
| 1326 | Hay, early cut, - | 8.13 | 11.44 | 3.62 | 41.71 | 30.08 | 5.02 | 1690 |
| 1327 | Hay, early cut, - | 8.47 | 11.11 | 3.58 | 39.25 | 32.29 | 5.30 | 1685 |
| 1328 | Hay, early cut, - | 7.85 | 11.24 | 3.48 | 41.37 | 30.67 | 5.39 | 1690 |
| | Average, - - | **8.31** | **11.18** | **3.59** | **40.65** | **31.04** | **5.23** | **1690** |
| 1263 | Hay, mixed grasses, | 13.64 | 6.06 | 3.04 | 45.50 | 27.37 | 4.39 | 1595 |
| 1264 | Hay, mixed grasses, | 13.22 | 5.74 | 2.99 | 43.23 | 30.39 | 4.43 | 1605 |
| 1268 | Hay, mixed grasses, | 14.18 | 9.09 | 3.01 | 42.60 | 25.92 | 5.20 | 1570 |
| 1277 | Hay, mixed grasses, | 7.25 | 8.81 | 3.45 | 47.56 | 27.04 | 5.89 | 1700 |
| 1290 | Hay, mixed grasses, | 10.79 | 5.91 | 2.52 | 46.25 | 30.25 | 4.28 | 1640 |
| | Average, - - | **11.82** | **7.12** | **3.00** | **45.03** | **28.19** | **4.84** | **1622** |
| 1288 | Clover hay, - - | 11.57 | 21.40 | 3.79 | 34.00 | 22.61 | 6.63 | 1615 |
| | *Seeds.* | | | | | | | |
| 1363 | Soy beans, - - | 14.53 | 34.36 | 15.48 | 26.17 | 4.25 | 5.21 | 1855 |
| 1364 | Soy beans, - - | 11.20 | 35.57 | 16.05 | 27.52 | 4.80 | 4.86 | 1935 |
| 1365 | Soy beans, - - | 15.33 | 36.00 | 15.37 | 24.92 | 3.85 | 4.53 | 1850 |
| | Average, - - | **13.69** | **35.31** | **15.63** | **26.20** | **4.30** | **4.87** | **1880** |
| 1303 | Oats and peas, - | 11.55 | 23.88 | 2.53 | 52.05 | 6.62 | 3.37 | 1640 |
| 1340 | Oats and peas, - | 11.38 | 22.25 | 2.48 | 52.95 | 7.65 | 3.29 | 1640 |
| | Average, - - | **11.46** | **23.07** | **2.51** | **52.50** | **7.13** | **3.33** | **1640** |
| | *Milling and By-Products.* | | | | | | | |
| 1265 | Corn meal, - - | 11.73 | 10.31 | 4.11 | 71.55 | 1.10 | 1.20 | 1715 |
| 1300 | Corn meal, - - | 12.44 | 10.19 | 4.31 | 70.55 | 1.27 | 1.24 | 1705 |
| 1305 | Corn meal, - - | 12.39 | 10.00 | 4.78 | 70.31 | 1.28 | 1.24 | 1715 |
| | Average, - - | **12.18** | **10.17** | **4.40** | **70.80** | **1.22** | **1.23** | **1710** |
| 1273 | Corn and cob meal, | 10.14 | 11.25 | 3.81 | 68.90 | 4.45 | 1.45 | 1735 |
| 1281 | Corn and cob meal, | 12.71 | 9.88 | 3.02 | 68.69 | 4.42 | 1.28 | 1670 |
| 1283 | Corn and cob meal, | 11.68 | 11.06 | 3.58 | 67.18 | 5.18 | 1.32 | 1705 |
| 1287 | Corn and cob meal, | 16.56 | 10.55 | 3.52 | 64.90 | 3.01 | 1.46 | 1605 |
| 1294 | Corn and cob meal, | 12.28 | 11.38 | 3.42 | 67.08 | 4.38 | 1.46 | 1685 |
| | Average, - - | **12.67** | **10.83** | **3.47** | **67.35** | **4.29** | **1.39** | **1680** |
| 1272 | Cob and rye meal, - | 15.83 | 9.99 | 3.10 | 67.96 | 1.66 | 1.46 | 1610 |
| 1266 | Wheat bran, - - | 7.46 | 16.75 | 5.14 | 55.96 | 8.71 | 5.98 | 1730 |
| 1271 | Wheat bran, - - | 9.28 | 20.44 | 6.01 | 50.51 | 8.82 | 4.94 | 1735 |
| 1275 | Wheat bran, - - | 8.30 | 17.13 | 4.77 | 55.35 | 8.76 | 5.69 | 1715 |
| 1280 | Wheat bran, - - | 8.25 | 19.69 | 4.74 | 52.64 | 8.98 | 5.70 | 1710 |
| 1284 | Wheat bran, - - | 8.41 | 18.25 | 5.28 | 53.08 | 9.24 | 5.74 | 1725 |
| | Average, - - | **8.34** | **18.45** | **5.19** | **53.51** | **8.90** | **5.61** | **1725** |

* For description of samples, see pages 17-20.

TABLE 1.—(*Continued.*)

| Lab. No. | KIND.* | Water. | Protein. | Fat. | Nit.-free Ext. | Fiber. | Ash. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|
| | *Milling and By-Products. (Continued.)* | % | % | % | % | % | % | Calories per lb. |
| 1299 | Wheat middlings, - | 10.03 | 20.88 | 6.44 | 49.96 | 7.95 | 4.74 | 1735 |
| 1291 | Linseed meal, - | 9.23 | 44.25 | 3.84 | 30.19 | 6.63 | 5.86 | 1690 |
| 1302 | Linseed mixture, - | 10.50 | 30.06 | 5.53 | 43.60 | 5.96 | 4.35 | 1715 |
| 1267 | Cotton seed meal, - | 7.30 | 48.19 | 9.13 | 24.09 | 4.22 | 7.07 | 1905 |
| 1292 | Cotton seed meal, - | 7.32 | 47.38 | 9.44 | 24.49 | 4.48 | 6.89 | 1820 |
| | Average, - - | **7.31** | **47.78** | **9.29** | **24.29** | **4.35** | **6.98** | **1865** |
| 1282 | Chicago gluten meal, | 9.83 | 33.81 | 4.02 | 49.71 | 1.76 | .87 | 1755 |
| 1286 | Chicago gluten meal, | 8.59 | 40.09 | 6.24 | 40.67 | 3.25 | 1.16 | 1825 |
| 1293 | Chicago gluten meal, | 8.64 | 33.38 | 4.66 | 50.33 | 2.12 | .87 | 1790 |
| | Average, - - | **9.02** | **35.76** | **4.97** | **46.90** | **2.38** | **.97** | **1790** |
| 1270 | Cream gluten meal, | 8.16 | 39.81 | 14.25 | 35.46 | 1.43 | .89 | 2030 |
| 1298 | Peoria gluten feed, - | 5.56 | 26.13 | 15.64 | 41.30 | 10.41 | .96 | 2105 |
| 1296 | Sheep feed, - - | 44.45 | 9.74 | 2.13 | 33.06 | 8.04 | 2.58 | 1055 |

TABLE 2.

*Proximate Composition of Fodders and Feeding Stuffs—Results of Analyses Herewith Reported, Calculated to Water-free Substance (Dry Matter).*

| Lab. No. | KIND.* | Protein. | Fat. | Nit.-free Ext. | Fiber. | Ash. | Fuel Value. |
|---|---|---|---|---|---|---|---|
| | *Green Fodders.* | % | % | % | % | % | Calories per lb. |
| 1359 | Orchard grass, - - - | 7.54 | 3.04 | 44.63 | 36.98 | 7.81 | 1785 |
| 1360 | Orchard grass, - - - | 7.17 | 2.83 | 43.21 | 38.14 | 8.65 | 1765 |
| 1361 | Orchard grass, - - - | 7.91 | 3.55 | 43.67 | 36.27 | 8.60 | 1780 |
| 1362 | Orchard grass, - - - | 10.61 | 3.45 | 41.61 | 36.24 | 8.09 | 1790 |
| | Average, - - - | **8.30** | **3.22** | **43.28** | **36.91** | **8.29** | **1780** |
| 1351 | Tall meadow fescue grass, - | 5.94 | 2.44 | 40.19 | 44.40 | 7.03 | 1765 |
| 1352 | Tall meadow fescue grass, - | 5.98 | 2.39 | 50.25 | 34.13 | 7.25 | 1775 |
| 1353 | Tall meadow fescue grass, - | 6.89 | 2.72 | 45.89 | 37.13 | 7.37 | 1785 |
| 1354 | Tall meadow fescue grass, - | 9.60 | 3.13 | 39.65 | 39.07 | 8.55 | 1774 |
| | Average, - - - | **7.10** | **2.67** | **44.00** | **38.68** | **7.55** | **1775** |
| 1347 | Tall meadow oat grass, - | 7.98 | 3.02 | 45.04 | 36.71 | 7.25 | 1795 |
| 1348 | Tall meadow oat grass, - | 7.57 | 3.17 | 44.08 | 37.44 | 7.74 | 1785 |
| 1349 | Tall meadow oat grass, - | 8.68 | 3.19 | 45.55 | 35.91 | 6.67 | 1805 |
| 1350 | Tall meadow oat grass, - | 11.52 | 3.39 | 42.56 | 35.70 | 6.85 | 1805 |
| | Average, - - - | **8.94** | **3.19** | **44.30** | **36.44** | **7.13** | **1800** |
| 1355 | Timothy, - - - - | 11.58 | 3.18 | 43.44 | 36.19 | 5.61 | 1825 |
| 1356 | Timothy, - - - - | 6.79 | 2.67 | 52.55 | 31.69 | 6.30 | 1800 |
| 1357 | Timothy, - - - - | 19.50 | 3.18 | 33.67 | 37.94 | 5.71 | 1825 |
| 1358 | Timothy, - - - - | 7.82 | 3.60 | 45.67 | 37.42 | 5.49 | 1655 |
| | Average, - - - | **11.42** | **3.16** | **43.83** | **35.81** | **5.78** | **1775** |

* For description of samples, see pages 17-20.

TABLE 2.—(*Continued.*)

| Lab. No. | KIND.* | Protein. | Fat. | Nit.-free Ext. | Fiber. | Ash. | Fuel Value. |
|---|---|---|---|---|---|---|---|
| | *Green Fodders. (Continued.)* | % | % | % | % | % | Calories per lb. |
| 1373 | Barley, - - - - | 16.06 | 3.96 | 44.66 | 26.61 | 8.71 | 1790 |
| 1372 | Barley, - - - - | 15.29 | 3.87 | 39.11 | 32.12 | 9.61 | 1770 |
| 1374 | Barley, - - - - | 15.71 | 3.88 | 44.04 | 27.19 | 9.18 | 1780 |
| 1376 | Barley, - - - - | 14.18 | 3.69 | 48.44 | 26.40 | 7.29 | 1810 |
| | Average, - - - | **15.31** | **3.85** | **44.06** | **28.08** | **8.70** | **1790** |
| 1369 | Barley and peas, - - | 20.86 | 4.44 | 40.20 | 25.72 | 8.78 | 1800 |
| 1371 | Barley and peas, - - | 19.16 | 3.99 | 41.16 | 26.32 | 9.37 | 1780 |
| 1373 | Barley and peas, - - | 20.74 | 4.79 | 42.44 | 24.28 | 7.75 | 1830 |
| 1375 | Barley and peas, - - | 19.44 | 3.53 | 43.36 | 25.96 | 7.71 | 1800 |
| | Average, - - - | **20.05** | **4.19** | **41.79** | **25.57** | **8.40** | **1805** |
| 1366 | Cow pea vines, - - - | 18.81 | 3.84 | 41.09 | 23.38 | 12.88 | 1710 |
| 1367 | Cow pea vines, - - - | 17.81 | 4.28 | 44.49 | 20.95 | 12.47 | 1725 |
| 1368 | Cow pea vines, - - - | 20.05 | 4.04 | 42.88 | 20.28 | 12.75 | 1680 |
| | Average, - - - | **18.89** | **4.05** | **42.82** | **21.54** | **12.70** | **1705** |
| 1341 | Scarlet clover, - - - | 19.58 | 5.03 | 39.37 | 25.52 | 10.50 | 1780 |
| 1342 | Scarlet clover, - - - | 16.92 | 4.06 | 43.20 | 27.10 | 8.72 | 1790 |
| 1343 | Scarlet clover, - - - | 18.08 | 4.65 | 39.60 | 27.04 | 10.03 | 1780 |
| | Average, - - - | **18.40** | **4.58** | **40.72** | **26.55** | **9.75** | **1785** |
| | *Ensilage.* | | | | | | |
| 1262 | Corn ensilage, - - - | 9.26 | 4.21 | 64.37 | 16.88 | 5.28 | 1860 |
| | *Cured Hay and Fodders.* | | | | | | |
| 1274 | Fodder, mostly stover, - | 7.59 | 2.86 | 47.85 | 35.44 | 6.26 | 1815 |
| 1269 | Corn stover, - - - | 6.75 | 2.58 | 51.38 | 33.43 | 5.86 | 1815 |
| 1279 | Corn stover, - - - | 10.68 | 2.49 | 55.73 | 23.90 | 7.20 | 1785 |
| 1289 | Corn stover, - - - | 9.28 | 2.21 | 49.43 | 32.07 | 7.01 | 1780 |
| | Average, - - - | **8.90** | **2.43** | **52.18** | **29.80** | **6.69** | **1795** |
| 1276 | Oat hay, - - - - | 9.10 | 4.01 | 50.37 | 29.88 | 6.64 | 1830 |
| 1278 | Oat hay, - - - - | 11.46 | 3.71 | 46.02 | 33.02 | 5.79 | 1840 |
| | Average, - - - | **10.28** | **3.86** | **48.20** | **31.45** | **6.21** | **1835** |
| 1297 | Timothy hay, - - - | 8.20 | 3.16 | 50.58 | 31.82 | 6.24 | 1815 |
| 1325 | Hay, early cut, - - - | 11.99 | 4.04 | 44.15 | 34.11 | 5.71 | 1845 |
| 1326 | Hay, early cut, - - - | 12.45 | 3.94 | 45.41 | 32.74 | 5.46 | 1850 |
| 1327 | Hay, early cut, - - - | 12.14 | 3.91 | 42.88 | 35.28 | 5.79 | 1845 |
| 1328 | Hay, early cut, - - - | 12.20 | 3.78 | 44.89 | 33.28 | 5.85 | 1835 |
| | Average, - - - | **12.20** | **3.92** | **44.33** | **33.85** | **5.70** | **1845** |
| 1263 | Hay from mixed grasses, - | 7.02 | 3.52 | 52.68 | 31.70 | 5.08 | 1850 |
| 1264 | Hay from mixed grasses, - | 6.61 | 3.44 | 49.83 | 35.02 | 5.10 | 1845 |
| 1268 | Hay from mixed grasses, - | 10.59 | 3.51 | 49.64 | 30.20 | 6.06 | 1830 |
| 1277 | Hay from mixed grasses, - | 9.50 | 3.72 | 51.27 | 29.16 | 6.35 | 1830 |
| 1290 | Hay from mixed grasses, - | 6.63 | 2.82 | 51.84 | 33.91 | 4.80 | 1835 |
| | Average, - - - | **8.07** | **3.40** | **51.05** | **32.00** | **5.48** | **1840** |
| 1288 | Clover hay, - - - | 24.20 | 4.28 | 38.45 | 25.57 | 7.50 | 1825 |
| | *Seeds.* | | | | | | |
| 1363 | Soy beans, - - - | 40.20 | 18.10 | 30.62 | 4.98 | 6.10 | 2175 |
| 1364 | Soy beans, - - - | 40.05 | 18.07 | 30.99 | 5.41 | 5.48 | 2180 |
| 1365 | Soy beans, - - - | 42.53 | 18.16 | 29.43 | 4.53 | 5.35 | 2185 |
| | Average, - - - | **40.93** | **18.11** | **30.35** | **4.97** | **5.64** | **2180** |

* For description of samples, see pages 17–20.

TABLE 2.—*(Continued.)*

| Lab. No. | KIND.* | Protein. | Fat. | Nit.-free Ext. | Fiber. | Ash. | Fuel Value. |
|---|---|---|---|---|---|---|---|
| | *Seeds. (Continued.)* | % | % | % | % | % | Calories per lb. |
| 1303 | Oats and peas, - - - | 27.00 | 2.86 | 58.85 | 7.48 | 3.81 | 1855 |
| 1340 | Oats and peas, - - - | 25.11 | 2.80 | 59.75 | 8.63 | 3.71 | 1855 |
| | Average, - - - | **26.05** | **2.83** | **59.30** | **8.06** | **3.76** | **1855** |
| | *Milling and By-Products.* | | | | | | |
| 1265 | Corn meal, - - - | 11.68 | 4.66 | 81.05 | 1.25 | 1.36 | 1945 |
| 1300 | Corn meal, - - - | 11.64 | 4.92 | 80.57 | 1.45 | 1.42 | 1950 |
| 1305 | Corn meal, - - - | 11.41 | 5.46 | 80.25 | 1.46 | 1.42 | 1960 |
| | Average, - - - | **11.57** | **5.01** | **80.63** | **1.39** | **1.40** | **1950** |
| 1273 | Corn and cob meal, - - | 12.52 | 4.24 | 76.68 | 4.95 | 1.61 | 1930 |
| 1281 | Corn and cob meal, - - | 11.32 | 3.46 | 78.69 | 5.06 | 1.47 | 1915 |
| 1283 | Corn and cob meal, - - | 12.52 | 4.05 | 76.07 | 5.87 | 1.49 | 1930 |
| 1287 | Corn and cob meal, - - | 12.65 | 4.22 | 77.77 | 3.61 | 1.75 | 1925 |
| 1294 | Corn and cob meal, - - | 12.97 | 3.90 | 76.48 | 4.99 | 1.66 | 1920 |
| | Average, - - - | **12.40** | **3.96** | **77.14** | **4.90** | **1.60** | **1925** |
| 1272 | Cob and rye meal, - - | 11.87 | 3.68 | 80.75 | 1.97 | 1.73 | 1915 |
| 1266 | Wheat bran, - - - | 18.10 | 5.56 | 60.47 | 9.41 | 6.46 | 1875 |
| 1271 | Wheat bran, - - - | 22.53 | 6.63 | 55.67 | 9.72 | 5.45 | 1915 |
| 1275 | Wheat bran, - - - | 18.68 | 5.20 | 60.36 | 9.55 | 6.21 | 1865 |
| 1280 | Wheat bran, - - - | 21.46 | 5.17 | 57.37 | 9.79 | 6.21 | 1865 |
| 1284 | Wheat bran, - - - | 19.93 | 5.76 | 57.95 | 10.09 | 6.27 | 1880 |
| | Average, - - - | **20.14** | **5.67** | **58.36** | **9.71** | **6.12** | **1880** |
| 1299 | Wheat middlings, - - | 23.21 | 7.16 | 55.53 | 8.83 | 5.27 | 1930 |
| 1291 | Linseed meal, - - - | 48.75 | 4.23 | 33.26 | 7.30 | 6.46 | 1840 |
| 1302 | Linseed mixture, - - | 33.59 | 6.17 | 48.72 | 6.66 | 4.86 | 1910 |
| 1267 | Cotton seed meal, - - | 51.99 | 9.85 | 25.98 | 4.55 | 7.63 | 1955 |
| 1292 | Cotton seed meal, - - | 51.12 | 10.19 | 26.43 | 4.83 | 7.43 | 1955 |
| | Average, - - - | **51.55** | **10.02** | **26.21** | **4.69** | **7.53** | **1955** |
| 1282 | Chicago gluten meal, - - | 37.49 | 4.46 | 55.13 | 1.95 | .97 | 1950 |
| 1286 | Chicago gluten meal, - - | 43.86 | 6.83 | 44.49 | 3.56 | 1.26 | 1995 |
| 1293 | Chicago gluten meal, - - | 36.54 | 5.10 | 55.09 | 2.32 | .95 | 1960 |
| | Average, - - - | **39.30** | **5.46** | **51.57** | **2.61** | **1.06** | **1970** |
| 1270 | Cream gluten meal, - - | 43.36 | 15.52 | 38.60 | 1.56 | .96 | 2205 |
| 1298 | Peoria gluten feed, - - | 27.67 | 16.56 | 43.73 | 11.02 | 1.02 | 2230 |
| 1296 | Sheep feed, - - - | 17.53 | 3.83 | 59.52 | 14.47 | 4.65 | 1865 |

* For description of samples, see pages 17–20.

# A STUDY OF RATIONS FED TO MILCH COWS IN CONNECTICUT.

[illegible] also Bul. 13

BY CHAS. D. WOODS AND C. S. PHELPS.

The study of rations fed to milch cows in this State, which was begun in the winter of 1892–93, has been continued, and at the time of this writing (December, 1894,) the third winter's examination of the actual feeding practice of Connecticut dairymen has been commenced. The first winter's work (1892–93) was described in detail in the Report of this Station for 1893, pp. 69–115. Some account* of this study was given at the winter meeting of the State Board of Agriculture at Hartford, in December, 1893, and it was the subject of Bulletin 13 of this Station. The results of the second winter's work (1893–94) are here reported.

Each herd was selected after a personal inspection, or after sufficient correspondence to satisfy ourselves of its fitness for the proposed test, and a representative of the Station was present during the whole period of each test and attended to the details of the experiment, such as weighing the feeding stuffs and taking samples for analyses, and weighing, sampling and determining the butter-fat in the milk. This work was faithfully performed by Mr. E. B. Fitts, at that time the Station Assistant in Farm Experiments.

In the first winter's work (1892–93), which was regarded as preliminary to an investigation that might extend over a series of years, it was thought better to examine a relatively large number of herds, each during a short period, than to make the periods longer and the number of herds less. Sixteen herds were visited and a five-days' test was made of each.

In the second winter's work, 1893–94, six different herds were visited, and in four cases the time of study of the management and products of each herd was extended to twelve days. The analyses of the feeding stuffs were made at once and the weights of nutrients in the rations as fed were calculated. In three

* Notes on Feeding Dairy Stock, by Chas. D. Woods; Report Conn. Board of Agriculture, 1893, pp. 182–199.

instances other rations were thereupon suggested by us as being better than the ones that had been used. The owners gradually changed the food to the ration thus proposed, and after an interval of four weeks from the close of the first test, another twelve-days' test was made of the same herd. A comparison was thus made of the yields of milk and butter-fat with the two different rations.

The chief points upon which information was obtained were:—

*Number of animals in the herd.*—In considering the number of animals, only those which came into the test were included. Usually these were all of the cows on the farm which were in milk at the time of the test.

*Breed, age and approximate weight of each cow.*—The breed and age were obtained as accurately as possible from the owner. Since it was not practicable to take to the farm scales large enough on which to weigh the cows, the weights were estimated. This estimation was made in each case by the Station representative, and it is hoped that the errors of judgment may run more or less equally through all the herds examined.

*Number of months since last calf.*—In most cases the time at which the cow dropped her last calf was known.

*Number of months till due to calve.*—There was, of course, more or less uncertainty in this regard.

*Weights of milk-flow for the five days.*—The milk of each cow at each milking was weighed as soon as milked, to the nearest tenth of a pound, by the Station representative.

*Percentages and amounts of butter-fat in the milk.*—A sample of the milk of each cow, at each milking, was taken for the determination of the quantity of butter-fat. The Babcock method of fat determination was employed. From the percentages of butter-fat in the milk, and the total weights of the milk, the daily yields of butter-fat were obtained.

*Kinds and weights of foods used.*—The feeder was requested to use the same kinds and amounts of feeding stuffs during the test period as he had previously used. The quantity for each animal was weighed by the Station representative just before feeding. Any portions of the food left uneaten by the cows were carefully weighed, and due allowance was made for these uneaten residues in estimating the amounts daily eaten. During the test, usually

on the third day, samples of each feeding stuff used were carefully taken and at once sent to the laboratory for analysis. From the results of the analyses and the weights fed, the total nutrients (protein, fat, nitrogen-free extract and fiber) fed each day were calculated. By the use of digestion coëfficients, estimates were made of the weights of digestible nutrients in each day's ration.

The names and post-office addresses of the owners of the herds studied by the Station are given in the following list, together with the dates at which the Station representative was at the farm. At the left, in the first column of figures, is a reference number for each test. In the remaining tables, and in the discussion, the herds entering into the tests and the rations fed are designated by these reference numbers.

*Names and Post-office Addresses of Owners of Herds Studied, Dates at which they were Visited and Reference Numbers of Tests.*

| NUMBER OF TEST. | NAME AND P. O. ADDRESS OF OWNER. | DATE OF TEST. |
|---|---|---|
| | | 1893. |
| 18, - - | W. S. Crane, Willimantic. | Dec. 4–16. |
| 19, - - | Harvey S. Ellis, Vernon Center. | Dec. 18–30. |
| | | 1894. |
| 20, - - | Clifton Peck, Lebanon. | Jan. 2–13. |
| 21, - - | Same herd as No. 18. | Jan. 15–27. |
| 22, - - | C. H. Lathrop, North Franklin. | Jan. 29–Feb. 10. |
| 23, - - | Same herd as No. 20. | Feb. 12–24. |
| 24, - - | W. F. Maine, South Windham. | Feb. 26–March 3. |
| 25, - - | Same herd as No. 22, | March 5–17. |
| 26, - - | Charles G. Nichols, West Willington. | March 19–24. |

The following abbreviations are used in the tables:

*Abbreviations Used in Report of Rations Fed to Milch Cows.*

| | | |
|---|---|---|
| Ay. = Ayrshire. | Gy. = Guernsey. | P. = Pure Breed. |
| Dev. = Devon. | Hol. = Holstein. | R. = Registered. |
| Dur. = Durham. | Jy. = Jersey. | Sw. = Swiss. |
| G. = Grade. | Nat. = Native. | |

Tables 3 to 11 inclusive contain the results, in considerable detail, of the studies of the different herds. They are all alike in arrangement, and a description of one will serve for all. Each table contains the condensed results of a test. Table 3, for instance, gives the statistics for test No. 18.

The first part of the upper table gives a reference number of each animal, its breed, age, weight and number of months since last calf. The smallest daily milk flow, the greatest daily milk flow and the average daily yield of milk for the period of the test are given in the next three columns. In the three following columns are given the lowest, highest and average percentages of fat found in the daily milk of each cow for the period. The figures were obtained by adding together the several daily determinations and taking the average, hence this actual average is not always half way between the highest and lowest. The yield of fat is given in the last three columns of the first or upper part of the table. The minimum and maximum yields of fats were obtained by multiplying each day's milk by its percentage of fat; the lowest number thus obtained gives the minimum daily yield of fat, and the largest the maximum yield of fat. It is to be noted that these numbers are not the same as would have been obtained by multiplying the minimum and maximum daily milk flow by the minimum and maximum percentages of fat.

The second, or lower part of each table, gives the kinds and amounts of the different feeding stuffs eaten *per day per 1,000 pounds live weight*, and the weights of the total and digestible nutrients (protein, fat and carbohydrates) which they furnished. As stated previously, all of the different feeding stuffs used in these rations were analysed, and from the results of these analyses the weights of the total nutrients furnished by the different coarse fodders and concentrated foods were obtained. The results of these analyses are given on pages 17–20 of this Report. The method employed in calculating the fuel value or potential energy furnished by the different foods, is referred to on page 17 of this Report.

The weights of digestible nutrients in the rations were obtained from the weights of total nutrients by the use of factors (coefficients of digestibility) obtained from the results of digestion experiments in this country and Germany. The following figures are taken from a paper* in which the results of nearly all American and other digestion experiments are summarized.

* Report of this Station for 1893, pp. 156–167.

*Coefficients of Digestibility used in calculating the Digestible Nutrients in the Different Feeding Stuffs used in these Rations.*

| | Protein. | Fat. | Carbohydrates. Nit.-free Ex. | Carbohydrates. Fiber. |
|---|---|---|---|---|
| | % | % | % | % |
| Wheat bran, | 78* | 76* | 72* | 33† |
| Linseed meal, | 86† | 90† | 80† | 50† |
| Cotton seed meal, | 89* | 100* | 68* | 33† |
| Pea meal, | 83* | 54* | 94* | 26* |
| Corn meal, | 76† | 92* | 87* | 58† |
| Corn and cob meal, | 76* | 82* | 84* | 28* |
| Gluten meal, | 87* | 88* | 91* | 33† |
| Malt sprouts, | 81† | 68† | 76† | 64† |
| Good quality hay, | 54* | 54* | 63* | 55* |
| Poor quality hay, | 45* | 28* | 60* | 46* |
| Rowen hay, | 62† | 46† | 67† | 64† |
| Corn stalks (stover), | 52* | 52* | 64* | 66* |
| Corn silage, | 46* | 80* | 67* | 67* |
| Turnips, etc., | 84* | 77* | 95* | 80* |

* From results of American digestion experiments.
† From results of German digestion experiments.

In order to show the range of variation from day to day in the feeding of the same herd, the minimum and maximum daily rations per 1,000 pounds live weight are appended to these tables. The size of the rations is here measured by the fuel value of the digestible nutrients (protein, fat, etc.) A ration which has a large fuel value may have a small amount of a given kind of food or a given kind of nutrients. Hence it sometimes happens that the minimum of one of the nutrients furnished by a certain kind of feeding stuff in a given ration may be greater than the average of the nutrients in that ration. This is the case with the minimum of the coarse food in ration 23, table 8. The same may happen conversely, in the case of the maximum.

TABLE 3.

*Dairy Test No. 18.—Statistics of Herd from Dec. 4 to 16, 1893.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. Min. | Max. | Avg. | Daily Percentage of Fat. Min. | Max. | Avg. | Daily Yield of Fat. Min. | Max. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | G. Jy., | 7 | 900 | 3 | 25.3 | 28.5 | **26.8** | 4.3 | 4.8 | **4.6** | 1.10 | 1.36 | **1.22** |
| 2 | G. Jy., | 7 | 875 | 5 | 22.1 | 25.3 | **23.3** | 4.4 | 5.1 | **4.8** | 1.03 | 1.19 | **1.11** |
| 3 | Gy., - | 3 | 800 | 8 | 6.3 | 7.6 | **7.2** | 5.3 | 6.3 | **5.9** | .34 | .46 | **.42** |
| 4 | Gy., - | 6 | 775 | 4 | 21.4 | 26.6 | **23.0** | 3.9 | 4.7 | **4.3** | .86 | 1.17 | **.98** |
| 5 | Jy., - | 6 | 825 | 4 | 19.5 | 25.7 | **22.4** | 4.3 | 5.0 | **4.7** | .97 | 1.17 | **1.06** |
| 6 | R. Gy., | 5 | 850 | 7 | 16.0 | 18.2 | **17.2** | 4.7 | 5.8 | **5.4** | .75 | .99 | **.92** |
| 7 | R. Gy., | 4 | 850 | 5 | 20.2 | 22.5 | **21.4** | 4.8 | 5.4 | **5.1** | .99 | 1.18 | **1.08** |
| 8 | H.G.Jy. | 5 | 800 | 4 | 10.8 | 12 3 | **11.6** | 5.6 | 6.2 | **5.9** | .60 | .74 | **.68** |
| 9 | R. Ay., | 3 | 700 | 10 | 11.8 | 23.9 | **14.1** | 3.8 | 4.2 | **4.0** | .46 | .98 | **.57** |
| 10 | G. Gy., | 6 | 950 | 9 | 12.4 | 13.8 | **13.2** | 4.7 | 5.3 | **5.0** | .60 | .71 | **.66** |
| 11 | D&Gy., | 3 | 925 | 5 | 16.4 | 23.0 | **20.4** | 3.9 | 4.6 | **4.3** | .67 | .99 | **.87** |
| 12 | R. Gy., | 10 | 850 | 8 | 6.9 | 13.3 | **9.1** | 4.8 | 6.4 | **5.5** | .41 | .64 | **.49** |
| 13 | G. Gy., | 8 | 900 | 2 | 27.7 | 32.3 | **29.3** | 4.4 | 5.0 | **4.7** | 1.27 | 1.50 | **1.38** |
| 14 | R. Gy., | 7 | 850 | 6 | 11.7 | 21.1 | **17.2** | 4.0 | 6.1 | **5.6** | .47 | 1.29 | **.98** |
| 15 | R. Gy., | 4 | 900 | 6 | 13.8 | 16.8 | **15.4** | 4.8 | 6.1 | **5.3** | .71 | 1.02 | **.82** |
| 16 | Jy., - | 4 | 725 | 4 | 12.8 | 21.8 | **19.2** | 5.6 | 6.5 | **6.0** | .73 | 1.42 | **1.16** |
| 17 | Jy., - | 4 | 700 | 3 | 13.5 | 20.5 | **18.1** | 3.9 | 5.6 | **4.3** | .65 | .91 | **.78** |
| 18 | G. Gy., | 4 | 800 | 5 | 13.9 | 18.2 | **17.0** | 5.4 | 7.2 | **6.5** | .75 | 1.24 | **1.11** |
| 19 | Gy., - | 2 | 750 | 3 | 13.2 | 16.6 | **14.4** | 4.3 | 5.7 | **5.1** | .58 | .88 | **.73** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Fed per Day. | Total Nutrients and Fuel Value. Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Digestible Nutrients and Fuel Value. Protein. | Fat. | Carbohydrates. | Nutritive Ratio. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Wheat bran, - | 6.2 | 1.03 | .32 | 3.46 | .54 | — | .80 | .23 | 2.46 | — | — |
| Corn meal, - | 4.6 | .47 | .19 | 3.29 | .05 | — | .35 | .18 | 2.88 | — | — |
| Cotton seed meal, | 1.5 | .73 | .14 | .36 | .06 | — | .65 | .14 | .27 | — | — |
| Total conc. food, | 12.3 | 2.23 | .65 | 7.11 | .65 | 21300 | 1.80 | .55 | 5.61 | 3.9 | 16100 |
| Ensilage, - - | 12.1 | .34 | .15 | 2.39 | .62 | — | .16 | .12 | 2.02 | — | — |
| Hay, - - | 20.1 | 1.19 | .61 | 8.92 | 5.81 | — | .64 | .33 | 8.82 | — | — |
| Total coarse food, | 32.2 | 1.53 | .76 | 11.31 | 6.43 | 39050 | .80 | .45 | 10.84 | 15.0 | 23600 |
| Total food, - | **44.5** | **3.76** | **1.41** | **18.42** | **7.08** | **60350** | **2.60** | **1.00** | **16.45** | **7.3** | **39700** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 12.6 | 2.23 | .65 | 7.36 | .67 | 21850 | 1.80 | .55 | 5.81 | 4.0 | 16500 |
| Coarse food, - | 28.9 | 1.36 | .67 | 9.99 | 5.61 | 34350 | .71 | .40 | 9.54 | 14.8 | 20750 |
| Total, - - | 41.5 | 3.59 | 1.32 | 17.35 | 6.28 | 56200 | 2.51 | .95 | 15.35 | 7.0 | 37250 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 12.3 | 2.37 | .65 | 7.03 | .60 | 21350 | 1.94 | .55 | 5.61 | 3.6 | 16350 |
| Coarse food, - | 36.8 | 1.75 | .87 | 12.98 | 7.40 | 44850 | .92 | .52 | 12.44 | 14.9 | 27050 |
| Total, - - | 49.1 | 4.12 | 1.52 | 20.1 | 8.00 | 66200 | 2.86 | 1.07 | 18.05 | 7.2 | 43400 |

TABLE 4.

*Dairy Test No. 19.—Statistics of Herd from Dec. 18 to 30, 1893.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. Min. | Max. | Avg. | Daily Percentage of Fat. Min. | Max. | Avg. | Daily Yield of Fat. Min. | Max. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | G. Jy., | 7 | 825 | 2 | 17.4 | 20.7 | **19.6** | 4.7 | 5.6 | **5.2** | .89 | 1.10 | **1.02** |
| 2 | G. Jy., | 6 | 875 | 1 | 27.2 | 30.3 | **28.6** | 4.0 | 4.7 | **4.3** | 1.15 | 1.42 | **1.25** |
| 3 | G. Jy., | 7 | 850 | 6 | 12.1 | 14.2 | **13.1** | 5.4 | 6.2 | **5.7** | .65 | .80 | **.75** |
| 4 | G. Jy., | 7 | 900 | 1 | 17.0 | 19.3 | **18.2** | 3.9 | 4.5 | **4.2** | .70 | .85 | **.76** |
| 5 | G. Dev., | 7 | 800 | 7 | 14.2 | 16.2 | **15.1** | 4.0 | 4.8 | **4.4** | .60 | .78 | **.67** |
| 6 | G. Jy., | 9 | 825 | 4 | 15.4 | 18.8 | **16.9** | 4.4 | 5.2 | **4.9** | .71 | .92 | **.82** |
| 7 | G. Jy., | 7 | 825 | 6 | 16.8 | 18.8 | **17.6** | 4.8 | 5.8 | **5.2** | .84 | 1.01 | **.92** |
| 8 | G. Jy., | 4 | 775 | 3 | 13.9 | 18.4 | **16.8** | 6.0 | 7.0 | **6.4** | .89 | 1.15 | **1.07** |
| 9 | G. Jy., | 10 | 950 | 30 | 13.3 | 19.2 | **15.3** | 5.8 | 7.4 | **6.8** | .94 | 1.18 | **1.04** |
| 10 | G. Jy., | 6 | 925 | 4 | 15.9 | 19.0 | **17.4** | 4.0 | 4.4 | **4.3** | .70 | .80 | **.74** |
| 11 | G. Jy., | 4 | 800 | 5 | 12.9 | 16.8 | **15.1** | 4.8 | 5.5 | **5.2** | .64 | .89 | **.78** |
| 12 | G. Jy., | 4 | 825 | 9 | 12.9 | 15.3 | **13.6** | 5.4 | 6.0 | **5.7** | .70 | .87 | **.78** |
| 13 | G. Jy., | 5 | 750 | 1 | 15.9 | 18.4 | **17.5** | 4.3 | 5.3 | **4.7** | .78 | .87 | **.82** |
| 14 | G. Jy., | 4 | 800 | 5 | 16.7 | 19.3 | **17.8** | 4.7 | 5.4 | **5.1** | .83 | .95 | **.90** |
| 15 | G. Jy., | 4 | 775 | 4 | 16.1 | 19.4 | **17.4** | 4.6 | 5.1 | **4.9** | .79 | .97 | **.84** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Fed per Day. | Total Nutrients and Fuel Value. Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Digestible Nutrients and Fuel Value. Protein. | Fat. | Carbohydrates. | Nutritive Ratio. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Corn and rye meal, | 3.8 | .38 | .12 | 2.58 | .06 | — | .29 | .11 | 2.27 | — | — |
| Gluten meal, - | 3.3 | 1.31 | .47 | 1.17 | .05 | — | 1.14 | .41 | 1.09 | — | — |
| Bran, - - | 3.6 | .73 | .21 | 1.80 | .31 | — | .57 | .16 | 1.29 | — | — |
| Total conc. food, | 10.7 | 2.42 | .80 | 5.55 | .42 | 19000 | 2.00 | .68 | 4.65 | 3.2 | 15200 |
| Fodder, - - | 18.9 | 1.32 | .48 | 8.25 | 5.24 | 29550 | .70 | .25 | 8.48 | 13.0 | 18100 |
| Total food, - | **29.6** | **3.74** | **1.28** | **13.80** | **5.66** | **48550** | **2.70** | **.93** | **13.13** | **5.7** | **33300** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 10.6 | 2.41 | .80 | 5.50 | .44 | 18900 | 1.98 | .67 | 4.59 | 3.2 | 15050 |
| Coarse food, - | 17.0 | 1.19 | .43 | 7.41 | 4.71 | 26600 | .63 | .23 | 7.61 | 13.0 | 16300 |
| Total, - - | 27.6 | 3.60 | 1.23 | 12.91 | 5.15 | 45500 | 2.61 | .90 | 12.20 | 5.6 | 31350 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 10.4 | 2.27 | .76 | 5.53 | .39 | 18450 | 1.87 | .65 | 4.67 | 3.4 | 14900 |
| Coarse food, - | 22.1 | 1.55 | .56 | 9.63 | 6.12 | 34550 | .82 | .30 | 9.89 | 13.0 | 21200 |
| Total, - - | 32.5 | 3.82 | 1.32 | 15.16 | 6.51 | 53000 | 2.69 | .95 | 14.56 | 6.3 | 36100 |

## TABLE 5.

*Dairy Test No. 20.—Statistics of Herd from Jan. 2 to 13, 1894.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. Min. | Daily Milk Flow. Max. | Daily Milk Flow. Avg. | Daily Percentage of Fat. Min. | Daily Percentage of Fat. Max. | Daily Percentage of Fat. Avg. | Daily Yield of Fat. Min. | Daily Yield of Fat. Max. | Daily Yield of Fat. Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | G. Jy., | 5 | 800 | 3 | 20.4 | 24.5 | **22.4** | 3.4 | 4.0 | **3.6** | .71 | .90 | **.81** |
| 2 | G. Jy., | 10 | 825 | 2 | 21.7 | 25.0 | **23.2** | 3.3 | 4.1 | **3.9** | .76 | .99 | **.90** |
| 3 | G. Jy., | 3 | 675 | 5 | 11.2 | 13.0 | **11.9** | 4.1 | 4.9 | **4.6** | .49 | .59 | **.55** |
| 4 | Native, | 12 | 725 | 9 | 8.5 | 10.3 | **9.5** | 4.1 | 5.0 | **4.5** | .35 | .52 | **.42** |
| 5 | Native, | 7 | 725 | 4 | 16.8 | 19.6 | **17.9** | 3.7 | 4.8 | **4.0** | .65 | .86 | **.72** |
| 6 | G. Jy., | 3 | 650 | 5 | 10.6 | 13.2 | **12.0** | 4.1 | 4.9 | **4.7** | .48 | .65 | **.56** |
| 7 | G. Jy., | 4 | 825 | 4 | 19.8 | 22.4 | **21.2** | 3.6 | 4.2 | **4.0** | .71 | .90 | **.84** |
| 8 | G. Jy., | 6 | 800 | 2 | 21.4 | 24.7 | **23.1** | 3.0 | 3.6 | **3.4** | .65 | .89 | **.78** |
| 9 | Native, | 5 | 850 | 3 | 18.9 | 22.0 | **20.4** | 4.2 | 4.9 | **4.6** | .79 | 1.02 | **.94** |
| 10 | Native, | 12 | 900 | 1 | 19.9 | 25.0 | **23.5** | 3.6 | 4.5 | **4.1** | .82 | 1.12 | **.95** |
| 11 | Native, | 12 | 825 | 1 | 22.9 | 28.4 | **25.5** | 3.4 | 4.3 | **3.8** | .82 | 1.16 | **.97** |
| 12 | Native, | 13 | 800 | 2 | 18.0 | 24.0 | **19.6** | 3.2 | 3.6 | **3.4** | .59 | .86 | **.67** |
| 13 | G. Jy., | 2 | 600 | 6 | 9.4 | 11.1 | **10.2** | 4.5 | 5.1 | **4.8** | .45 | .53 | **.49** |
| 14 | G. Jy., | 5 | 800 | 2 | 17.1 | 20.3 | **18.9** | 3.9 | 4.9 | **4.5** | .73 | .97 | **.85** |
| 15 | G. Jy., | 2 | 600 | 5 | 9.1 | 15.2 | **10.5** | 4.5 | 5.0 | **4.7** | .43 | .76 | **.50** |
| 16 | G. Jy., | 2 | 600 | 5 | 10.1 | 15.7 | **11.5** | 4.9 | 5.5 | **5.1** | .51 | .83 | **.59** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Feed per Day. | Total Nutrients and Fuel Value. Protein. | Total. Fat. | Total. Nit.-free Ext. | Total. Fiber. | Total. Fuel Value. | Digestible Nutrients and Fuel Value. Protein. | Digestible. Fat. | Digestible. Carbohydrates. | Digestible. Nutritive Ratio. | Digestible. Fuel Value. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Cob meal, - - | 8.3 | .94 | .32 | 5.74 | .37 | — | .71 | .26 | 4.92 | — | — |
| Bran, - - | 3.8 | .65 | .18 | 2.11 | .33 | — | .51 | .13 | 1.50 | — | — |
| Total conc. food, | 12.1 | 1.59 | .50 | 7.85 | .70 | 20950 | 1.22 | .39 | 6.42 | 6.1 | 15800 |
| Fodder, - - | 16.1 | .89 | .34 | 5.62 | 4.16 | — | .40 | .09 | 5.29 | — | — |
| Oat hay, - - | 8.4 | .64 | .28 | 3.54 | 2.10 | — | .35 | .16 | 3.38 | — | — |
| Total coarse food, | 24.5 | 1.53 | .62 | 9.16 | 6.26 | 34150 | .75 | .25 | 8.67 | 12.4 | 18600 |
| Total food, - | **36.6** | **3.12** | **1.12** | **17.01** | **6.96** | **55100** | **1.97** | **.64** | **15.09** | **8.5** | **34400** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 12.5 | 1.62 | .52 | 8.11 | .71 | 21600 | 1.24 | .41 | 6.66 | 6.2 | 16400 |
| Coarse food, - | 20.2 | 1.28 | .52 | 7.59 | 5.16 | 28300 | .63 | .22 | 7.19 | 12.3 | 15500 |
| Total, - - | 32.7 | 2.90 | 1.04 | 15.70 | 5.87 | 49900 | 1.87 | .63 | 13.85 | 8.2 | 31900 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 12.5 | 1.64 | .52 | 8.08 | .72 | 21600 | 1.26 | .41 | 6.61 | 6.1 | 16400 |
| Coarse food, - | 28.9 | 1.78 | .71 | 10.72 | 7.40 | 40000 | .86 | .28 | 10.14 | 12.6 | 21600 |
| Total, - - | 41.4 | 3.42 | 1.23 | 18.80 | 8.12 | 61600 | 2.12 | .69 | 16.75 | 8.7 | 38000 |

## TABLE 6.

*Dairy Test No. 21.—Statistics of Herd from Jan. 15 to 27, 1894.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. Min. | Max. | Avg. | Daily Percentage of Fat. Min. | Max. | Avg. | Daily Yield of Fat. Min. | Max. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | G. Dev., | 7 | 850 | 1 | 37.3 | 41.1 | **39.3** | 3.9 | 4.5 | **4.2** | 1.53 | 1.74 | **1.65** |
| 2 | G. Jy., | 7 | 875 | 5 | 20.4 | 23.8 | **22.0** | 4.4 | 5.1 | **4.8** | .98 | 1.16 | **1.06** |
| 3 | G. Sw., | 6 | 925 | 1 | 30.4 | 33.6 | **31.8** | 4.2 | 4.7 | **4.5** | 1.29 | 1.58 | **1.42** |
| 4 | Gy., | 6 | 775 | 4 | 14.2 | 23.5 | **21.4** | 4.1 | 4.5 | **4.3** | .61 | 1.05 | **.92** |
| 5 | Jy., | 6 | 825 | 4 | 17.4 | 21.6 | **19.6** | 4.2 | 5.0 | **4.6** | .78 | .99 | **.89** |
| 6 | R. Gy., | 5 | 850 | 7 | 17.7 | 20.2 | **19.2** | 4.3 | 5.2 | **4.9** | .87 | 1.01 | **.94** |
| 7 | R. Gy., | 4 | 850 | 5 | 21.9 | 25.0 | **22.9** | 4.6 | 5.5 | **5.1** | 1.01 | 1.35 | **1.16** |
| 8 | G. Jy., | 6 | 775 | 0 | 20.6 | 28.7 | **24.9** | 4.6 | 5.4 | **5.0** | 1.05 | 1.49 | **1.26** |
| 9 | R. Ay., | 3 | 700 | 10 | 9.9 | 11.5 | **10.6** | 4.1 | 4.6 | **4.3** | .41 | .51 | **.45** |
| 10 | Gy., | 20 m | 700 | 2 | 11.5 | 13.8 | **12.3** | 4.0 | 4.7 | **4.3** | .47 | .59 | **.53** |
| 11 | D & Gy., | 3 | 925 | 5 | 19.7 | 24.6 | **22.2** | 3.9 | 4.8 | **4.4** | .92 | 1.02 | **.96** |
| 12 | R. Gy., | 10 | 850 | 8 | 8.3 | 10.0 | **9.3** | 5.0 | 5.9 | **5.5** | .45 | .58 | **.51** |
| 13 | G. Gy., | 8 | 900 | 2 | 25.0 | 28.5 | **26.7** | 4.3 | 5.0 | **4.6** | 1.10 | 1.34 | **1.23** |
| 14 | R. Gy., | 7 | 850 | 6 | 16.9 | 19.2 | **18.2** | 5.0 | 5.6 | **5.2** | .87 | 1.05 | **.95** |
| 15 | R. Gy., | 4 | 900 | 6 | 13.4 | 16.9 | **14.8** | 4.8 | 5.5 | **5.1** | .69 | .86 | **.75** |
| 16 | Jy., | 4 | 725 | 4 | 18.5 | 22.4 | **20.2** | 5.7 | 6.5 | **6.1** | 1.11 | 1.34 | **1.23** |
| 17 | Jy., | 4 | 700 | 3 | 21.6 | 25.2 | **23.1** | 3.3 | 4.5 | **3.9** | .72 | 1.00 | **.91** |
| 18 | G. Gy., | 4 | 800 | 5 | 14.4 | 19.9 | **17.4** | 5.6 | 6.8 | **6.3** | .92 | 1.35 | **1.09** |
| 19 | G. Gy., | 2 | 750 | 3 | 14.6 | 16.8 | **15.5** | 5.1 | 5.7 | **5.3** | .74 | .91 | **.82** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Fed per Day. | Total Nutrients and Fuel Value. Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Digestible Nutrients and Fuel Value. Protein. | Fat. | Carbohydrates. | Nutritive Ratio. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Grain, - - | 12.5 | 2.74 | .72 | 6.65 | .72 | 21850 | 2.19 | .59 | 5.15 | 3.0 | 16100 |
| Hay, - - | 9.7 | .57 | .29 | 4.29 | 2.80 | — | .31 | .16 | 4.24 | — | — |
| Ensilage, - - | 15.3 | .43 | .20 | 3.02 | .79 | — | .20 | .16 | 2.55 | — | — |
| Oat hay, - - | 4.9 | .38 | .14 | 2.13 | 1.37 | — | .20 | .08 | 2.09 | — | — |
| Total coarse food, | 29.9 | 1.38 | .63 | 9.44 | 4.96 | 32000 | .71 | .40 | 8.88 | 13.9 | 19500 |
| Total food, - | **42.4** | **4.12** | **1.35** | **16.09** | **5.68** | **53850** | **2.90** | **.99** | **14.03** | **5.7** | **35600** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 11.0 | 2.41 | .63 | 5.85 | .63 | 19200 | 1.93 | .52 | 4.53 | 3.0 | 14200 |
| Coarse food, - | 31.4 | 1.42 | .64 | 9.70 | 5.00 | 32700 | .73 | .41 | 9.08 | 13.8 | 20000 |
| Total, - - | 42.4 | 3.83 | 1.27 | 15.55 | 5.63 | 51900 | 2.66 | .93 | 13.61 | 6.0 | 34200 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 13.3 | 2.91 | .76 | 7.07 | .77 | 23200 | 2.33 | .63 | 5.47 | 3.0 | 17200 |
| Coarse food, - | 29.7 | 1.37 | .62 | 9.34 | 4.89 | 31650 | .70 | .39 | 8.77 | 13.9 | 19200 |
| Total, - - | 43.0 | 4.28 | 1.38 | 16.41 | 5.66 | 54850 | 3.03 | 1.02 | 14 24 | 5.5 | 36400 |

## TABLE 7.

*Dairy Test No. 22.—Statistics of Herd from Jan. 29 to Feb. 10, 1894.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. Min. | Max. | Avg. | Daily Percentage of Fat. Min. | Max. | Avg | Daily Yield of Fat. Min. | Max. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | Native, | 11 | 875 | 2 | 16.4 | 19.0 | **17.7** | 4.5 | 4.9 | **4.7** | .79 | .89 | **.83** |
| 2 | G. Dur., | 8 | 900 | 2 | 17.0 | 19.7 | **18.3** | 3.4 | 3.9 | **3.7** | .58 | .77 | **.67** |
| 3 | G. Dur., | 7 | 900 | 2 | 21.1 | 23.8 | **22.7** | 3.5 | 4.0 | **3.8** | .80 | .95 | **.86** |
| 4 | G. Jy., | 9 | 750 | 4 | 14.2 | 17.1 | **15.8** | 3.5 | 3.9 | **3.8** | .53 | .67 | **.60** |
| 5 | Native, | 5 | 600 | 1 | 18.1 | 21.6 | **20.3** | 3.4 | 4.0 | **3.6** | .66 | .79 | **.74** |
| 6 | G. Jy., | 4 | 750 | 1 | 17.4 | 19,9 | **18.7** | 3.0 | 3.6 | **3.3** | .53 | .72 | **.62** |
| 7 | G. Jy., | 3 | 600 | 9 | 7.5 | 11.2 | **8.8** | 3.6 | 4.0 | **3.8** | .29 | .41 | **.34** |
| 8 | G. Jy., | 9 | 725 | 4 | 15.4 | 17.3 | **16.0** | 4.0 | 4.8 | **4.3** | .63 | .74 | **.69** |
| 9 | Native, | 3 | 600 | 9 | 8.6 | 9.6 | **9.0** | 4.3 | 5.0 | **4.7** | .38 | .46 | **.42** |
| 10 | G. Jy., | 10 | 850 | 12 | 8.1 | 9.6 | **9.2** | 3.9 | 4.8 | **4.1** | .33 | .42 | **.38** |
| 11 | G. Gy., | 4 | 800 | 8 | 5.9 | 8.0 | **6.9** | 4.3 | 4.8 | **4.6** | .27 | .37 | **.32** |
| 12 | Native, | 3 | 700 | 9 | 9.6 | 12.3 | **11.0** | 3.6 | 4.1 | **3.9** | .36 | .48 | **.42** |
| 13 | Native, | 3 | 825 | 9 | 9.0 | 15.1 | **13.5** | 3.6 | 4.3 | **3.9** | .39 | .61 | **.53** |
| 14 | Native, | 3 | 650 | 11 | 8.5 | 10.5 | **9.2** | 4.8 | 5.4 | **5.1** | .42 | .53 | **.47** |
| 15 | G. Jy., | 4 | 625 | 11 | 2.5 | 7.4 | **6.4** | 5.2 | 5.9 | **5.5** | .15 | .40 | **.35** |
| 16 | G. Jy., | 3 | 575 | 11 | 4.2 | 5.9 | **5.0** | 4.2 | 5.0 | **4.6** | .18 | .28 | **.23** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Fed per Day. | Total Nutrients and Fuel Value. Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Digestible Nutrients and Fuel Value. Protein. | Fat. | Carbohydrates. | Nutritive Ratio. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Cob meal, - - | 5.9 | .58 | .18 | 4.07 | .26 | — | .44 | .15 | 3.49 | — | — |
| Wheat bran, - | 4.1 | .80 | .19 | 2.18 | .35 | — | .62 | .14 | 1.56 | — | — |
| Total conc. food, | 10.0 | 1.38 | .37 | 6.25 | .61 | 16900 | 1.06 | .29 | 5.05 | 5.4 | 12600 |
| Stover, - - | 4.8 | .48 | .11 | 2.49 | 1.06 | — | .25 | .06 | 2.29 | — | — |
| Oat hay, - - | 5.4 | .58 | .19 | 2.33 | 1.67 | — | .31 | .10 | 2.39 | — | — |
| Hay, - - - | 6.2 | .54 | .21 | 2.95 | 1.68 | — | .29 | .11 | 2.78 | — | — |
| Total coarse food, | 16.4 | 1.60 | .51 | 7.77 | 4.41 | 27800 | .85 | .27 | 7.46 | 9.6 | 16600 |
| Total food, - | **26.4** | **2.98** | **.88** | **14.02** | **5.02** | **44700** | **1.91** | **.56** | **12.51** | **7.3** | **29200** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 9.8 | 1.36 | .37 | 6.08 | .62 | 16550 | 1.05 | .29 | 4.92 | 5.4 | 12300 |
| Coarse food, - | 13.4 | 1.33 | .47 | 6.04 | 3.91 | 22950 | .72 | .25 | 5.96 | 9.2 | 13500 |
| Total, - - | 23.2 | 2.69 | .84 | 12.12 | 4.53 | 39500 | 1.77 | .54 | 10.88 | 6.9 | 25800 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 10.2 | 1.42 | .38 | 6.33 | .65 | 17250 | 1.10 | .30 | 5.12 | 5.3 | 12850 |
| Coarse food, - | 18.1 | 1.70 | .51 | 9.01 | 4.41 | 30250 | .90 | .27 | 8.39 | 10.1 | 18400 |
| Total, - - | 28.3 | 3.12 | .89 | 15.34 | 5.06 | 47500 | 2.00 | .57 | 13.51 | 7.5 | 31250 |

## Table 8.

*Dairy Test No. 23.—Statistics of Herd from Feb. 12 to 24, 1894.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. Min. | | | Daily Percentage of Fat. Min. | | | Daily Yield of Fat. Min. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. |
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | G. Jy., | 5 | 800 | 3 | 19.5 | 23.2 | **21.3** | 3.6 | 4.1 | **3.9** | .78 | .90 | **.82** |
| 2 | G. Jy., | 10 | 825 | 2 | 22.3 | 24.8 | **24.0** | 3.7 | 4.1 | **3.9** | .89 | 1.01 | **.94** |
| 3 | G. Jy., | 3 | 675 | 5 | 11.4 | 13.8 | **12.2** | 4.6 | 5.2 | **4.8** | .53 | .65 | **.59** |
| 4 | G. Jy., | 3 | 750 | 1 | 21.2 | 23.9 | **22.4** | 3.7 | 4.6 | **4.0** | .80 | 1.07 | **.89** |
| 5 | Native, | 7 | 725 | 4 | 15.8 | 17.5 | **16.6** | 3.7 | 4.2 | **3.9** | .58 | .69 | **.64** |
| 6 | G. Jy., | 3 | 650 | 5 | 12.1 | 13.9 | **13.0** | 4.8 | 5.2 | **5.1** | .62 | .70 | **.67** |
| 7 | G. Jy., | 4 | 825 | 4 | 20.8 | 23.0 | **22.0** | 3.8 | 4.4 | **4.1** | .85 | .97 | **.90** |
| 8 | G. Jy., | 6 | 800 | 2 | 21.1 | 23.4 | **22.3** | 3.4 | 3.7 | **3.5** | .72 | .85 | **.78** |
| 9 | Native, | 5 | 850 | 3 | 18.8 | 23.3 | **20.3** | 4.4 | 4.9 | **4.7** | .88 | 1.03 | **.95** |
| 10 | Native, | 12 | 900 | 1 | 18.3 | 23.2 | **20.0** | 4.0 | 4.6 | **4.3** | .75 | 1.06 | **.86** |
| 11 | Native, | 12 | 825 | 1 | 20.6 | 23.3 | **22.1** | 3.3 | 3.9 | **3.7** | .72 | .87 | **.81** |
| 12 | Native, | 13 | 800 | 2 | 19.3 | 22.3 | **20.3** | 3.4 | 3.7 | **3.5** | .66 | .80 | **.71** |
| 13 | G. Jy., | 2 | 600 | 6 | 11.0 | 14.4 | **12.2** | 4.5 | 5.3 | **4.9** | .53 | .72 | **.59** |
| 14 | G. Gy., | 5 | 800 | 2 | 16.2 | 19.1 | **18.0** | 4.1 | 4.9 | **4.5** | .73 | .89 | **.81** |
| 15 | G. Jy., | 2 | 600 | 5 | 10.5 | 12.3 | **10.8** | 4.4 | 4.8 | **4.6** | .47 | .59 | **.50** |
| 16 | G. Jy., | 2 | 600 | 5 | 12.4 | 15.0 | **13.5** | 4.9 | 7.5 | **5.7** | .61 | 1.10 | **.77** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Fed per Day. | Total Nutrients and Fuel Value. Protein. | | | | | Digestible Nutrients and Fuel Value. Protein. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Protein. | Fat. | Carbohydrates. | Nutritive Ratio. | Fuel Value. |
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Corn and cob meal, | 3.3 | .36 | .12 | 2.18 | .17 | — | .27 | .10 | 1.88 | — | — |
| Bran, - - | 5.4 | .99 | .29 | 2.88 | .50 | — | .77 | .21 | 2.06 | — | — |
| Gluten meal, - | 3.1 | 1.06 | .12 | 1.56 | .06 | — | .92 | .11 | 1.44 | — | — |
| Total conc. food, | 11.8 | 2.41 | .53 | 6.62 | .73 | 20400 | 1.96 | .42 | 5.38 | 3.3 | 15400 |
| Fodder, - - | 13.6 | .75 | .28 | 4.76 | 3.52 | — | .34 | .07 | 4.47 | — | — |
| Oat hay, - - | 9.2 | .70 | .31 | 3.87 | 2.30 | — | .38 | .17 | 3.70 | — | — |
| Total coarse food, | 22.8 | 1.45 | .59 | 8.63 | 5.82 | 32050 | .72 | .24 | 8.17 | 12.2 | 17550 |
| Total food, - | **34.6** | **3.86** | **1.12** | **15.25** | **6.55** | **52450** | **2.68** | **.66** | **13.55** | **5.7** | **32950** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 10.8 | 2.20 | .48 | 6.05 | .67 | 18600 | 1.80 | .38 | 4.91 | 3.3 | 14100 |
| Coarse food, - | 23 2 | 1.48 | .60 | 8.77 | 5.92 | 32600 | .73 | .25 | 8.31 | 12.2 | 17850 |
| Total, - - | 34.0 | 3.68 | 1.08 | 14.82 | 6.59 | 51200 | 2.53 | .63 | 13.22 | 5.8 | 31950 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 11.8 | 2.41 | .53 | 6.61 | .73 | 20350 | 1.97 | .42 | 5.36 | 3.3 | 15400 |
| Coarse food, - | 24.0 | 1.53 | .61 | 9.07 | 6.12 | 33700 | .75 | .25 | 8.58 | 12.3 | 18400 |
| Total, - - | 35.8 | 3.94 | 1.14 | 15.68 | 6.85 | 54050 | 2.72 | .67 | 13.94 | 5.8 | 33800 |

TABLE 9.

*Dairy Test No. 24.—Statistics of Herd from Feb. 26 to March 3, 1894.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. | | | Daily Percentage of Fat. | | | Daily Yield of Fat. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. |
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | P. Jy., | 3 | 750 | 4 | 20.1 | 21.6 | **20.9** | 3.8 | 4.0 | **3.9** | .76 | .83 | **.81** |
| 2 | G. Jy., | 3 | 650 | 10 | 16.4 | 17.8 | **17.1** | 5.0 | 5.1 | **5.1** | .84 | .89 | **.87** |
| 3 | P. Jy., | 5 | 775 | 6 | 16.6 | 17.0 | **16.8** | 5.0 | 5.4 | **5.2** | .85 | .92 | **.88** |
| 4 | G. Jy., | 6 | 800 | 0 | 23.2 | 26.2 | **24.8** | 3.2 | 3.6 | **3.4** | .74 | .89 | **.84** |
| 5 | Native, | 10 | 725 | 11 | 13.8 | 14.7 | **14.2** | 5.4 | 5.7 | **5.5** | .77 | .80 | **.79** |
| 6 | G. Dev., | 6 | 800 | 2 | 22.8 | 24.1 | **23.5** | 3.2 | 3.9 | **3.6** | .75 | .92 | **.84** |
| 7 | G. Jy., | 9 | 800 | 2 | 20.2 | 22.5 | **21.0** | 4.4 | 4.7 | **4.6** | .93 | 1.04 | **.96** |
| 8 | G. Jy., | 7 | 825 | 6 | 16.3 | 18.9 | **17.6** | 4.6 | 5.0 | **4.9** | .81 | .95 | **.87** |
| 9 | G. Jy., | 5 | 800 | 4 | 12.0 | 13.6 | **12.9** | 4.4 | 4.8 | **4.6** | .54 | .65 | **.60** |
| 10 | G. Jy., | 4 | 850 | 5 | 14.9 | 16.7 | **15.7** | 5.0 | 5.3 | **5.2** | .77 | .84 | **.81** |
| 11 | P. Gy., | 3 | 775 | 1 | 23.6 | 25.6 | **25.0** | 4.7 | 5.0 | **4.9** | 1.13 | 1.28 | **1.21** |
| 12 | G. Jy., | 12 | 800 | 2 | 24.6 | 27.1 | **25.9** | 3.2 | 3.4 | **3.3** | .84 | .89 | **.86** |
| 13 | G. Jy., | 5 | 750 | 2 | 16.2 | 19.0 | **17.7** | 4.9 | 5.0 | **4.9** | .79 | .93 | **.87** |
| 14 | G. Jy., | 3 | 750 | 1 | 24.8 | 25.8 | **25.3** | 4.3 | 4.4 | **4.4** | 1.07 | 1.13 | **1.11** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Fed per Day. | Total Nutrients and Fuel Value. | | | | | Digestible Nutrients and Fuel Value. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Protein. | Fat. | Carbohydrates. | Nutritive Ratio. | Fuel Value. |
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Grain, | 13.6 | 2.49 | .62 | 7.78 | .56 | 22750 | 1.97 | .51 | 6.54 | 4.0 | 18000 |
| Stover, | 3.4 | .27 | .06 | 1.43 | .92 | — | .16 | .04 | 1.63 | — | — |
| Clover hay, | 8.3 | 1.78 | .31 | 2.82 | 1.88 | — | 1.08 | .15 | 2.69 | — | — |
| Hay, | 8.7 | .51 | .22 | 4.00 | 2.62 | — | .27 | .12 | 3.96 | — | — |
| Total coarse food, | 20.4 | 2.56 | .59 | 8.25 | 5.42 | 32700 | 1.51 | .31 | 8.28 | 6.0 | 19500 |
| Total food, | **34.0** | **5.05** | **1.21** | **16.03** | **5.98** | **55450** | **3.48** | **.82** | **14.82** | **4.8** | **37500** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 13.6 | 2.49 | .62 | 7.79 | .56 | 22800 | 1.97 | .51 | 6.55 | 4.0 | 18000 |
| Coarse food, | 19.8 | 2.46 | .60 | 8.14 | 5.36 | 32200 | 1.44 | .30 | 7.95 | 6.0 | 18700 |
| Total, | 33.4 | 4.95 | 1.22 | 15.93 | 5.92 | 55000 | 3.41 | .81 | 14.50 | 4.8 | 36700 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 13.8 | 2.53 | .63 | 7.90 | .57 | 23100 | 2.00 | .51 | 6.65 | 4.0 | 18300 |
| Coarse food, | 20.6 | 2.71 | .58 | 8.08 | 5.29 | 32350 | 1.61 | .32 | 8.43 | 5.7 | 20000 |
| Total, | 34.4 | 5.24 | 1.21 | 15.98 | 5.86 | 55450 | 3.61 | .83 | 15.08 | 4.8 | 38300 |

TABLE 10.

*Dairy Test No. 25.—Statistics of Herd from March 5 to 17, 1894.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. Min. | Max. | Avg. | Daily Percentage of Fat. Min. | Max. | Avg. | Daily Yield of Fat. Min. | Max. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | Native, | 11 | 875 | 2 | 16.3 | 18.9 | **17.6** | 4.8 | 5.8 | **5.1** | .82 | .98 | **.91** |
| 2 | G. Dur., | 8 | 900 | 2 | 17.7 | 20.1 | **18.8** | 3.7 | 4.1 | **3.9** | .67 | .82 | **.74** |
| 3 | G. Dur., | 7 | 900 | 2 | 21.0 | 24.3 | **22.6** | 4.0 | 4.3 | **4.1** | .86 | 1.00 | **.93** |
| 4 | G. Jy., | 9 | 750 | 4 | 15.2 | 18.8 | **17.0** | 3.6 | 4.0 | **3.8** | .55 | .71 | **.65** |
| 5 | Native, | 5 | 600 | 1 | 19.2 | 23.2 | **21.3** | 3.5 | 3.9 | **3.7** | .73 | .84 | **.78** |
| 6 | G. Jy., | 4 | 750 | 1 | 16.2 | 18.7 | **18.0** | 3.9 | 4.4 | **4.1** | .69 | .78 | **.73** |
| 7 | G. Jy., | 3 | 600 | 9 | 9.1 | 11.2 | **10.3** | 3.9 | 4.3 | **4.1** | .36 | .46 | **.42** |
| 8 | G. Jy., | 9 | 725 | 4 | 15.1 | 17 9 | **16.7** | 4.2 | 4.7 | **4.4** | .67 | .81 | **.73** |
| 9 | Native, | 3 | 600 | 9 | 9.2 | 11.1 | **10.2** | 4.8 | 5.3 | **5.0** | .45 | .55 | **.51** |
| 12 | Native, | 3 | 700 | 9 | 10.2 | 12.8 | **11.6** | 3.8 | 4.5 | **4.1** | .44 | .54 | **.48** |
| 13 | Native, | 3 | 825 | 9 | 15.0 | 17.9 | **16.3** | 3.9 | 4.3 | **4.0** | .59 | .73 | **.66** |
| 14 | Native, | 3 | 650 | 11 | 9.4 | 11.9 | **10.6** | 5.0 | 5.7 | **5.4** | .49 | .66 | **.57** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Fed per Day. | Total Nutrients and Fuel Value. Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Digestible Nutrients and Fuel Value. Protein. | Fat. | Carbohydrates. | Nutritive Ratio. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Grain, - - | 10.8 | 2.03 | .49 | 6.14 | .66 | 18500 | 1.60 | .40 | 5.06 | 3.8 | 14100 |
| Oat hay, - - | 8.1 | .87 | .28 | 3.50 | 2.51 | — | .47 | .15 | 3.59 | — | — |
| Hay, - - | 8.7 | .76 | .30 | 4.13 | 2.35 | — | .41 | .16 | 3.89 | — | — |
| Total coarse food, | 16.8 | 1.63 | .58 | 7.63 | 4.86 | 28700 | .88 | .31 | 7.48 | 9.4 | 16800 |
| Total food, - | **27.6** | **3.66** | **1.07** | **13.77** | **5.52** | **47200** | **2.48** | **.71** | **12.54** | **5.8** | **30900** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 10.0 | 1.87 | .45 | 5.66 | .62 | 17050 | 1.48 | .37 | 4.66 | 3.8 | 13000 |
| Coarse food, - | 16.1 | 1.57 | .55 | 7.31 | 4.68 | 27550 | .84 | .30 | 7.19 | 9.4 | 16200 |
| Total, - - | 26.1 | 3.44 | 1.00 | 12.97 | 5.30 | 44600 | 2.32 | .67 | 11.85 | 5.8 | 29200 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 11.4 | 2.13 | .52 | 6.46 | .70 | 19450 | 1.68 | .43 | 5.32 | 3.8 | 14800 |
| Coarse food, - | 17.6 | 1.71 | .61 | 8.00 | 5.09 | 30100 | .93 | .33 | 7.84 | 9.3 | 17700 |
| Total, - - | 29.0 | 3.84 | 1.13 | 14.46 | 5.79 | 49550 | 2.61 | .76 | 13.16 | 5.8 | 32500 |

TABLE II.

*Dairy Test No. 26.—Statistics of Herd from March 19 to 24, 1894.*

| Ref. No. | Breed. | Age. | Weight. | Mos. Since Last Calf. | Daily Milk Flow. | | | Daily Percentage of Fat. | | | Daily Yield of Fat. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Min. | Max. | Avg. | Min. | Max. | Avg. | Min. | Max. | Avg. |
| | | Yrs. | Lbs. | Mos. | Lbs. | Lbs. | Lbs. | % | % | % | Lbs. | Lbs. | Lbs. |
| 1 | G. Jy., | 8 | 800 | 4 | 13.7 | 14.8 | **14.4** | 5.2 | 5.3 | **5.2** | .73 | .77 | **.75** |
| 2 | G. Hol., | 12 | 850 | 17 | 11.6 | 14.2 | **12.8** | 4.9 | 5.6 | **5.2** | .61 | .71 | **.66** |
| 3 | Native, | 8 | 900 | 16 | 10.5 | 12.4 | **11.1** | 4.7 | 4.9 | **4.8** | .49 | .60 | **.53** |
| 4 | G. Jy., | 11 | 825 | 9 | 13.6 | 16.1 | **14.8** | 5.3 | 5.8 | **5.5** | .72 | .89 | **.82** |
| 5 | G. Jy., | 12 | 850 | 15 | 14.6 | 15.6 | **15.0** | 5.5 | 6.2 | **5.8** | .82 | .93 | **.88** |
| 6 | Native, | 11 | 800 | 9 | 15.4 | 16.3 | **15.9** | 5.1 | 5.7 | **5.4** | .83 | .91 | **.86** |
| 7 | G. Jy., | 8 | 850 | 21 | 7.8 | 9.0 | **8.6** | 4.8 | 5.0 | **4.9** | .39 | .43 | **.42** |
| 8 | Native, | 9 | 950 | 19 | 13.8 | 16.1 | **14.7** | 4.4 | 4.8 | **4.5** | .63 | .71 | **.67** |
| 9 | Native, | 4 | 850 | 19 | 7.7 | 8.8 | **8.4** | 5.7 | 6.5 | **6.2** | .48 | .55 | **.52** |
| 10 | G. Jy., | 4 | 750 | 1 | 22.4 | 25.0 | **23.6** | 3.1 | 3.9 | **3.6** | .69 | .89 | **.84** |
| 11 | G. Jy., | 4 | 825 | 7 | 12.5 | 13.3 | **12.9** | 5.4 | 5.8 | **5.6** | .68 | .77 | **.72** |
| 12 | G. Jy., | 5 | 800 | 1 | 20.1 | 27.6 | **24.6** | 3.4 | 3.6 | **3.5** | .68 | .99 | **.86** |
| 13 | G. Jy., | 3 | 700 | 9 | 6.3 | 7.7 | **7.2** | 6.5 | 6.8 | **6.6** | .41 | .50 | **.48** |
| 14 | G. Jy., | 3 | 675 | 11 | 5.8 | 6.4 | **6.1** | 6.1 | 6.8 | **6.4** | .36 | .43 | **.39** |
| 15 | G. Jy., | 3 | 700 | 12 | 6.4 | 8.3 | **7.2** | 5.8 | 8.1 | **6.8** | .38 | .67 | **.50** |

*Pounds of Food and Nutrients per Day per 1,000 Lbs., Live Weight.*

| Kinds of Feed. | Average Fed per Day. | Total Nutrients and Fuel Value. | | | | | Digestible Nutrients and Fuel Value. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Protein. | Fat. | Nit-free Ext. | Fiber. | Fuel Value. | Protein. | Fat. | Carbohydrates. | Nutritive Ratio. | Fuel Value. |
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| Gluten meal, - | 3.5 | .92 | .55 | 1.45 | .36 | — | .80 | .48 | 1.44 | — | — |
| Middlings, - | 7.1 | 1.48 | .46 | 3.53 | .56 | — | 1.15 | .35 | 2.72 | — | — |
| Total conc. food, | 10.6 | 2.40 | 1.01 | 4.98 | .92 | 19700 | 1.95 | .83 | 4.16 | 3.2 | 14900 |
| Hay, - - | 14.3 | 1.05 | .40 | 6.46 | 4.06 | 23200 | .57 | .22 | 6.31 | 12.1 | 13700 |
| Total food, - | **24.9** | **3.45** | **1.41** | **11.44** | **4.98** | **42900** | **2.52** | **1.05** | **10.47** | **5.2** | **28600** |
| *Minimum per day.* | | | | | | | | | | | |
| Concentrated food, | 11.0 | 2.49 | 1.04 | 5.19 | .97 | 20450 | 2.03 | .85 | 4.34 | 3.1 | 15400 |
| Coarse food, - | 10.0 | .73 | .28 | 4.52 | 2.85 | 16250 | .39 | .15 | 4.42 | 12.3 | 9600 |
| Total, - - | 21.0 | 3.22 | 1.32 | 9.71 | 3.82 | 36700 | 2.42 | 1.00 | 8.76 | 4.7 | 25000 |
| *Maximum per day.* | | | | | | | | | | | |
| Concentrated food, | 10.8 | 2.45 | 1.04 | 5.08 | .94 | 20150 | 1.99 | .86 | 4.26 | 3.2 | 15200 |
| Coarse food, - | 15.2 | 1.11 | .43 | 6.88 | 4.32 | 24700 | .60 | .23 | 6.71 | 12.1 | 14600 |
| Total, - - | 26.0 | .56 | 1.47 | 11.96 | 5.26 | 44850 | 2.59 | 1.09 | 10.97 | 5.4 | 29800 |

TABLE 12.

*Summary of Total and Digestible Nutrients Fed per Day per 1,000 Lbs., Live Weight, on Dairy Farms in Connecticut.*

| Reference No. | Classes of Food. | Total Nutrients and Fuel Value. | | | | | Digestible Nutrients and Fuel Value. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Protein. | Ash. | Nit.-free Ext. | Fiber. | Fuel Value. | Protein. | Fat. | Carbo-hydrates. | Nutritive Ratio. | Fuel Value. |
| | | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| 1 | Concentrated food, | 1.87 | .64 | 4.00 | .65 | 14800 | 1.58 | .55 | 3.51 | — | 11790 |
| | Coarse food, - | 1.80 | .70 | 9.61 | 6.17 | 35700 | .93 | .44 | 9.73 | — | 21660 |
| | Total food, - | **3.67** | **1.34** | **13.61** | **6.82** | **50500** | **2.51** | **.99** | **13.24** | **6.2** | **33450** |
| 2 | Concentrated food, | 2.51 | .56 | 6.22 | .70 | 19900 | 2.05 | .49 | 5.58 | — | 16300 |
| | Coarse food, - | 1.49 | .57 | 9.17 | 6.00 | 33400 | .74 | .36 | 9.61 | — | 20700 |
| | Total food, - | **4.00** | **1.13** | **15.39** | **6.70** | **53300** | **2.79** | **.85** | **15.19** | **6.1** | **37000** |
| 3 | Concentrated food, | 2.71 | .96 | 5.11 | .63 | 19700 | 2.39 | .87 | 4.65 | — | 16770 |
| | Coarse food, - | 1.20 | .54 | 10.10 | 5.64 | 33800 | .62 | .28 | 10.13 | — | 21180 |
| | Total food, - | **3.91** | **1.50** | **15.21** | **6.27** | **53500** | **3.01** | **1.15** | **14.78** | **5.7** | **37950** |
| 4 | Concentrated food, | 1.81 | .55 | 6.27 | .54 | 18300 | 1.47 | .46 | 4.99 | — | 14000 |
| | Coarse food, - | 2.14 | .86 | 11.94 | 7.06 | 43000 | 1.15 | .47 | 11.67 | — | 25800 |
| | Total food, - | **3.95** | **1.41** | **18.21** | **7.60** | **61300** | **2.62** | **.93** | **16.66** | **7.0** | **39800** |
| 5 | Concentrated food, | 2 64 | .88 | 3.39 | .31 | 15500 | 2.20 | .76 | 2.64 | — | 12200 |
| | Coarse food, - | 1.90 | .73 | 12.43 | 7.31 | 43300 | .96 | .49 | 12.55 | — | 27200 |
| | Total food, - | **4.54** | **1.61** | **15.82** | **7.62** | **58800** | **3.16** | **1.25** | **15.19** | **5.7** | **39400** |
| 6 | Concentrated food, | 1.56 | .54 | 4.19 | .20 | 13400 | 1.23 | .51 | 3.58 | — | 11100 |
| | Coarse food, - | 1.49 | .67 | 11.04 | 6.90 | 38900 | .80 | .36 | 10.97 | — | 23400 |
| | Total food, - | **3.05** | **1.21** | **15.23** | **7.10** | **52300** | **2.03** | **.87** | **14.55** | **8.1** | **34500** |
| 7 | Concentrated food, | 1.97 | .74 | 8.96 | .51 | 24400 | 1.44 | .65 | 7.70 | — | 19740 |
| | Coarse food, - | 1.86 | .81 | 11.23 | 5.87 | 38700 | 1.00 | .44 | 10.30 | — | 22860 |
| | Total food, - | **3.83** | **1.55** | **20.19** | **6.38** | **63100** | **2.44** | **1.09** | **18.00** | **8.4** | **42600** |
| 8 | Concentrated food, | 2.08 | .64 | 6.47 | 1.23 | 20900 | 1.60 | .50 | 5.35 | — | 15050 |
| | Coarse food, - | 2.98 | .79 | 11.75 | 7.74 | 45100 | 1.56 | .43 | 11.60 | — | 26300 |
| | Total food, - | **5.06** | **1.43** | **18.22** | **8.97** | **66000** | **3.16** | **.93** | **16.95** | **6.0** | **41350** |
| 9 | Concentrated food, | 1.62 | .65 | 3.81 | .22 | 13240 | 1.20 | .58 | 3.14 | — | 10500 |
| | Coarse food, - | 1.68 | .49 | 8.68 | 5.62 | 31760 | .96 | .25 | 8.91 | — | 19450 |
| | Total food, - | **3.30** | **1.14** | **12.49** | **5.84** | **45000** | **2.16** | **.83** | **12.05** | **6.4** | **29950** |

TABLE 12.—*(Continued.)*

| Reference No. | Classes of Food. | Total Nutrients and Fuel Value. Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Digestible Nutrients and Fuel Value. Protein. | Fat. | Carbo-hydrates. | Nutritive Ratio. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| 10 | Concentrated food, | 1.57 | .55 | 4.62 | .27 | 14300 | 1.09 | .50 | 3.72 | — | 11100 |
| | Coarse food, - | 2.11 | .67 | 9.16 | 5.47 | 34000 | 1.23 | .34 | 9.32 | — | 21000 |
| | Total food, - | **3.68** | **1.22** | **13.78** | **5.74** | **48300** | **2.32** | **.84** | **13.04** | **6.4** | **32100** |
| 11 | Concentrated food, | 2.51 | .78 | 5.20 | .43 | 18400 | 1.91 | .70 | 4.17 | — | 14250 |
| | Coarse food, - | 1.58 | .57 | 8.98 | 6.35 | 33900 | .85 | .31 | 9.29 | — | 20200 |
| | Total food, - | **4.09** | **1.35** | **14.18** | **6.78** | **52300** | **2.76** | **1.01** | **13.46** | **5.7** | **34450** |
| 12 | Concentrated food, | 2.96 | .66 | 6.40 | 1.03 | 22100 | 2.29 | .56 | 4.84 | — | 15650 |
| | Coarse food, - | 1.40 | .57 | 6.38 | 3.95 | 24200 | .70 | .38 | 6.57 | — | 15100 |
| | Total food, - | **4.36** | **1.23** | **12.78** | **4.98** | **46300** | **2.99** | **.94** | **11.41** | **4.5** | **30750** |
| 13 | Concentrated food, | 2.25 | .72 | 6.13 | .56 | 19600 | 1.67 | .64 | 5.27 | — | 15600 |
| | Coarse food, - | 1.03 | .42 | 5.97 | 3.38 | 21100 | .53 | .28 | 5.90 | — | 13150 |
| | Total food, - | **3.28** | **1.14** | **12.10** | **3.94** | **40700** | **2.20** | **.92** | **11.17** | **6.0** | **28750** |
| 14 | Concentrated food, | 2.23 | .85 | 4.95 | .38 | 17690 | 1.71 | .64 | 3.79 | — | 12900 |
| | Coarse food, - | 1.77 | .76 | 9.77 | 5.47 | 34810 | .95 | .41 | 9.30 | — | 20850 |
| | Total food, - | **4.00** | **1.61** | **14.72** | **5.85** | **52500** | **2.66** | **1.05** | **13.09** | **5.8** | **33750** |
| 15 | Concentrated food, | .92 | .46 | 5.82 | .28 | 15000 | .70 | .37 | 4.79 | — | 11800 |
| | Coarse food, - | 1.21 | .36 | 9.24 | 5.55 | 31300 | .65 | .19 | 9.20 | — | 19100 |
| | Total food, - | **2.13** | **.82** | **15.06** | **5.83** | **46300** | **1.35** | **.56** | **13.99** | **11.3** | **30900** |
| 16 | Concentrated food, | .82 | .53 | 4.33 | .28 | 12340 | .61 | .46 | 3.74 | — | 10100 |
| | Coarse food, - | 1.54 | .63 | 9.56 | 5.10 | 32760 | .83 | .34 | 8.92 | — | 19500 |
| | Total food, - | **2.36** | **1.16** | **13.89** | **5.38** | **45100** | **1.44** | **.80** | **12.66** | **9.3** | **29600** |
| 18 | Concentrated food, | 2.23 | .65 | 7.11 | .65 | 21300 | 1.80 | .55 | 5.61 | 3.9 | 16100 |
| | Coarse food, - | 1.53 | .76 | 11.31 | 6.43 | 39050 | .80 | .45 | 10.84 | 15.0 | 23600 |
| | Total food, - | **3.76** | **1.41** | **18.42** | **7.08** | **60350** | **2.60** | **1.00** | **16.45** | **7.3** | **39700** |
| 19 | Concentrated food, | 2.42 | .80 | 5.55 | .42 | 19000 | 2.00 | .68 | 4.65 | 3.2 | 15200 |
| | Coarse food, - | 1.32 | .48 | 8.25 | 5.24 | 29550 | .70 | .25 | 8.48 | 13.0 | 18100 |
| | Total food, - | **3.74** | **1.28** | **13.80** | **5.66** | **48550** | **2.70** | **.93** | **13.13** | **5.7** | **33300** |
| 20 | Concentrated food, | 1.59 | .50 | 7.85 | .70 | 20950 | 1.22 | .39 | 6.42 | 6.1 | 15800 |
| | Coarse food, - | 1.53 | .62 | 9.16 | 6.26 | 34150 | .75 | .25 | 8.67 | 12.4 | 18600 |
| | Total food, - | **3.12** | **1.12** | **17.01** | **6.96** | **55100** | **1.97** | **.64** | **15.09** | **8.5** | **34400** |

TABLE 12.—*(Continued.)*

| Reference No. | Classes of Food. | Total Nutrients and Fuel Value. | | | | | Digestible Nutrients and Fuel Value. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Protein. | Fat. | Nit.-free Ext. | Fiber. | Fuel Value. | Protein. | Fat. | Carbo-hydrates. | Nutritive Ratio. | Fuel Value. |
| | | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. | Lbs. | 1: | Cal. |
| 21 | Concentrated food, | 2.74 | .72 | 6.65 | .72 | 21850 | 2.19 | .59 | 5.15 | 3.0 | 16100 |
| | Coarse food, - | 1.38 | .63 | 9.44 | 4.96 | 32000 | .71 | .40 | 8.88 | 13.9 | 19500 |
| | Total food, - | **4.12** | **1.35** | **16.09** | **5.68** | **53850** | **2.90** | **.99** | **14.03** | **5.7** | **35600** |
| 22 | Concentrated food, | 1.38 | .37 | 6.25 | .61 | 16900 | 1.06 | .29 | 5.05 | 5.4 | 12600 |
| | Coarse food, - | 1.60 | .51 | 7.77 | 4.41 | 27800 | .85 | .27 | 7.46 | 9.6 | 16600 |
| | Total food, - | **2.98** | **.88** | **14.02** | **5.02** | **44700** | **1.91** | **.56** | **12.51** | **7.3** | **29200** |
| 23 | Concentrated food, | 2.41 | .53 | 6.62 | .73 | 20400 | 1.96 | .42 | 5.38 | 3.3 | 15400 |
| | Coarse food, - | 1.45 | .59 | 8.63 | 5.82 | 32050 | .72 | .24 | 8.17 | 12.2 | 17550 |
| | Total food, - | **3.86** | **1.12** | **15.25** | **6.55** | **52450** | **2.68** | **.66** | **13.55** | **5.7** | **32950** |
| 24 | Concentrated food, | 2.49 | .62 | 7.78 | .56 | 22750 | 1.97 | .51 | 6.54 | 4.0 | 18000 |
| | Coarse food, - | 2.56 | .59 | 8.25 | 5.42 | 32700 | 1.51 | .31 | 8.28 | 6.0 | 19500 |
| | Total food, - | **5.05** | **1.21** | **16.03** | **5.98** | **55450** | **3.48** | **.82** | **14.82** | **4.8** | **37500** |
| 25 | Concentrated food, | 2.03 | .49 | 6.14 | .66 | 18500 | 1.60 | .40 | 5.06 | 3.8 | 14100 |
| | Coarse food, - | 1.63 | .58 | 7.63 | 4.86 | 28700 | .88 | .31 | 7.48 | 9.4 | 16800 |
| | Total food, - | **3.66** | **1.07** | **13.77** | **5.52** | **47200** | **2.48** | **.71** | **12.54** | **5.8** | **30900** |
| 26 | Concentrated food, | 2.40 | 1.01 | 4.98 | .92 | 19700 | 1.95 | .83 | 4.16 | 3.2 | 14900 |
| | Coarse food, - | 1.05 | .40 | 6.46 | 4.06 | 23200 | .57 | .22 | 6.31 | 12.1 | 13700 |
| | Total food, - | **3.45** | **1.41** | **11.44** | **4.98** | **42900** | **2.52** | **1.05** | **10.47** | **5.2** | **28600** |
| | *Average of the above 25 rations.* | | | | | | | | | | |
| | Concentrated food, - - - - - - - | | | | | | 1.63 | .55 | 4.78 | 3.6 | 14250 |
| | Coarse food, - - - - - - - - | | | | | | .88 | .35 | 9.14 | 11.3 | 20100 |
| | Total food, - - - - - - - - | | | | | | **2.51** | **.90** | **13.92** | **6.3** | **34350** |
| | *Average of 22 of the above rations.** | | | | | | | | | | |
| | Concentrated food, - - - - - - - | | | | | | 1.59 | .56 | 4.72 | 3.1 | 14050 |
| | Coarse food, - - - - - - - - | | | | | | .89 | .35 | 9.23 | 11.3 | 20200 |
| | Total food, - - - - - - - - | | | | | | **2.48** | **.91** | **13.95** | **6.4** | **34250** |

* Three of the 25 rations (Nos. 21, 23 and 25) were suggested by the authors. Hence the 22 rations, the average of which is here given, actually represent the feeding practices of these dairymen.

Table 12, on pages 40 to 42, gives a summary of twenty-five rations fed on dairy farms in Connecticut. In the first five columns are given the total nutrients and the total fuel value in the materials fed. The three following columns give the calculated weights of digestible protein, fats and carbohydrates. As explained on page 30, these weights are calculated from the total nutrients by the use of factors (digestion coefficients) obtained from digestion experiments. These factors are only approximate, and the weights of nutrients obtained by their use are also approximate. The next column contains the nutritive ratio and the last column gives the fuel value of the digestible nutrients in the rations.

It will be seen from table 12 that the smallest weight of digestible protein fed per day per 1,000 pounds live weight, was 1.35 pounds, and the largest amount was 3.48 pounds. The fuel value of the digestible nutrients fed per 1,000 pounds live weight, varied from a minimum of 28,600 Calories to a maximum of 42,600 Calories. There was also a correspondingly large range in the nutritive ratio of the rations fed. The narrowest ration had the ratio of 1:4.5; the widest, of 1:11.3.

## EXPLANATIONS.

*Uses of food.*—The two chief uses of food are to form the materials of the body and make up its wastes, and to yield energy in the form of heat to keep the body warm and in the form of muscular and other power for the work it has to do. The principal tissue-formers of the food are the protein or nitrogenous compounds. They build up and repair the nitrogenous materials, as the muscle and bone, and supply the albuminoids of blood, milk, and other fluids, The chief fuel ingredients of the food are the carbohydrates (such as sugar, starch, etc.,) and fat. These are either consumed in the body or stored as fat to be used as occasion demands.

*Fuel value.*—The value of food as fuel may be measured in terms of potential energy. The unit commonly used is the Calorie. One Calorie is the amount of heat necessary to raise the temperature of a pound of water about four degrees Farenheit.* From experiment it has been found that a pound of protein or carbohydrates yields, when burned, about 1,860 Calories of fuel value and that a pound of fat yields about 4,220 Calories.

* The Calorie is exactly the heat necessary to raise the temperature of 1 kilogram of water one degree Centigrade.

*Nutritive ratio.*—There is a very important relation between the amounts of protein (flesh formers) and the amounts of fuel constituents of a food. This relation is expressed by the nutritive ratio. The fuel value of fat is about two and one-fourth times that of the carbohydrates and the protein, hence it happens that if the sum of the digestible carbohydrates and two and one-fourth times the digestible fat of a ration is divided by the amount of digestible protein in the ration, the quotient gives what is called the nutritive ratio.

*Wide ration.—Narrow ration.*—If the quantities of digestible fat and carbohydrates are large relative to the protein, the nutritive ratio will be a large number and the ration is called a "wide ration;" if the quantities of digestible fat and carbohydrates are relatively small, the quotient is a small number and the ration is a "narrow" one. A ration where the nutritive ratio is much more than 1:6 may be called a "wide ration;" if much less it may be called a "narrow ration."

Nearly all of the grasses and hays have a large nutritive ratio, and the same is true of corn and many of its products, such as meal and hominy chops. The use of such feeding stuffs will tend to make a ration wide. The legumes such as clover, peas, vetch, etc., and many of the products of milling and food manufacture are relatively rich in protein, and hence have small nutritive ratios. Wide rations are much more common among American feeders than are narrow ones. Narrow rations would be better. Practically it is probably unwise to feed a ration whose nutritive ratio is greater than that of one to six or seven.

*The measure of the size of a ration.*—In order that a ration may be complete, there must be enough digestible protein supplied in the food to build new tissues (bone, muscle, milk, etc.,) and repair the wastes of the body, and sufficient digestible fat and carbohydrates to furnish heat and muscular energy. As the chief function of the fat and carbohydrates is to serve as fuel, it is more important that enough of these should be provided to meet the needs of the animal than that they should be supplied in definite relative proportions. It is, therefore, possible to form a very good idea of the nutrients furnished in a ration, and to measure its size by the quantity of digestible protein or flesh-formers which it contains, and the fuel value of its digestible constituents.

### DISCUSSION OF THE RESULTS OF THE TESTS.

The results brought out in such a study as the one here reported are tentative rather than final. This investigation was not undertaken with the expectation of obtaining startling facts, nor would we be warranted in drawing very definite conclusions from the tests. We do believe, however, that there is much of practical importance to be obtained along this line of inquiry, and that the results herewith presented merit the careful attention of dairymen.

It is probably true that the animals of most of the herds examined were, so far as breed, milk and butter product are concerned, above the average of cows kept for dairy purposes in Connecticut. It is doubtless true that the feeding practiced by the owners of these herds is better than that which is generally practiced throughout the State. These facts, taken together with the shortness of the periods of observation to which the herds were subjected, have been kept in mind in the following discussion of the results of the tests, which is reprinted from Bulletin 13 of this Station.

### A RATION FOR A MILCH COW.

A proper daily ration will supply, in appropriate forms, the protein needed to form the nitrogenous materials of the body and the energy required for heat and muscular work, and a proper feeding standard will call for sufficient digestible protein, fats, and carbohydrates per day to meet these needs. But just what these weights should be is a matter of considerable uncertainty. Differences in breed and individual peculiarities of the animals, and in the food and handling, as well as other conditions, known and unknown, bring it about that the best rations for one cow may not be the best for another. The feeder must know his cows and fit the food to their wants. But in so doing he may be greatly helped by feeding standards.

In the following table are given the commonly quoted standard ration proposed twenty-five or more years ago by Prof. Wolff, an eminent German chemist and experimenter; the average of 128 American rations as ascertained by the Wisconsin Experiment Station; the average of 16 rations fed in Connecticut in 1893, and of 25 fed in 1893 and 1894; and a tentatively suggested ration.

*German (Wolff's) Standard Ration, together with Averages of Some American Rations and a Tentatively Suggested Ration per 1,000 Lbs., Live Weight.*

| Ration. | Organic Matter. | Digestible Nutrients. Protein. | Fat. | Carbohydrates. | Fuel Value. | Nutritive †Ratio. |
|---|---|---|---|---|---|---|
| | Lbs. | Lbs. | Lbs. | Lbs. | Calories. | 1: |
| Wolff's (German) Standard, - - - - | 24.0 | 2.50 | .40 | 12.50 | 29,600 | 5.4 |
| Average of 128 American rations compiled by the Wisconsin Experiment Station,* - - - | 24.5 | 2.15 | .74 | 13.27 | 31,250 | 6.9 |
| Average of 16 rations as fed in Connecticut in 1892–93, - - - | 26.4 | 2.48 | .94 | 14.09 | 34,800 | 6.5 |
| Average of 25 rations as fed in Connecticut in 1892–94, - - - | 26.8 | 2.51 | .90 | 13.92 | 34,350 | 6.3 |
| Tentatively suggested ration, - - - - | 25.0 | 2.50 | (.5 to .8)† | (13 to 12)† | 31,000† | 5.6 |

* Wisconsin Experiment Station, Bulletin 38.

† In this suggested ration the fuel value could be supplied by about .5 of a pound of digestible fat and 13.0 pounds digestible carbohydrates; by .6 of a pound of digestible fat and 12.5 pounds of digestible carbohydrates; or by .8 of a pound of digestible fat and 12 pounds of digestible carbohydrates.

The German figures in the above table are based upon observations of the feeding practices of the best German feeders, and a large number of feeding experiments conducted by trained specialists, chiefly in experiment stations.

The 128 rations compiled by the Wisconsin Experiment Station were obtained in response to letters sent to "dairy farmers and breeders of dairy stock in all parts of the United States and Canada, asking information concerning their methods of feeding milch cows." The average of these rations represents the average of the feeding practice of American dairymen as ascertained from the more or less accurate estimates of the feeders themselves as to amounts fed, etc. The materials fed were not analyzed, but their composition was assumed from the averages of other analyses. The Wisconsin Station proposes* this average as an "American standard ration for dairy cows."

The Connecticut rations given in the table represent the actual feeding practices of the dairymen whose herds were examined, so far as could be learned by weighing the foods actually fed

* Wisconsin Agricultural Experiment Station, Bulletin 38, p. 46.

from day to day, and by determining their composition by chemical analysis. The factors used for calculating the quantities of digestible nutrients are the chief sources of uncertainty here, but this uncertainty is at present inevitable.

In Germany there is a tendency to the more liberal use of protein. The ration proposed by the Wisconsin Station advocates less protein and more of the fuel ingredients of the food. Because carbohydrates and fats are so abundant and so cheap in this country that we feed them liberally does not imply, much less prove, that we are using them wisely.

## Wide vs. Narrow Rations.

RESULTS OF TESTS IN 1892–93.

There are so few American data upon the effects of rations, that the teachings of the studies of the herds made by the Station upon this question are of some value.

*Summary of rations fed and yields of butter obtained from sixteen herds examined in 1892-93. The yields of butter are classified in accordance with the nutritive ratios of the ration and the amounts of digestible protein which they contain.*

| Summary of Rations Fed Per Head. | | | | | | Daily Average Yields of Butter* Per Cow. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Nutritive Ratio. | | Digestible Protein. | |
| Herd No. | Average Weight of Cows. | Total Organic Matter. | Digestible Protein. | Nutritive Ratio. | Fuel Value of Digestible Nutrients. | Greater than 1:6. Wider Rations. | Less than 1:6. Narrower Rations. | More than 2.2 Pounds.† | Less than 2.2 Pounds.† |
| | Lbs. | Lbs. | Lbs. | 1: | Cal. | Lbs. | Lbs. | Lbs. | Lbs. |
| 1, - - | 900 | 22.9 | 2.25 | 6.0 | 30,100 | — | 1.1 | 1.1 | — |
| 2, - - | 800 | 21.8 | 2.24 | 6.0 | 29,600 | — | 1.0 | 1.0 | — |
| 3, - - | 800 | 21.5 | 2.40 | 5.5 | 30,350 | — | 1.2 | 1.2 | — |
| 4, - - | 800 | 25.0 | 2.08 | 7.0 | 31,850 | 0.8 | — | 0.8 | — |
| 5, - - | 800 | 23.7 | 2.52 | 5.5 | 31,500 | — | 1.0 | 1.0 | — |
| 6, - - | 900 | 23.9 | 1.85 | 8.0 | 31,050 | 0.9 | — | — | 0.9 |
| 7, - - | 800 | 25.6 | 1.96 | 8.5 | 34,100 | 1.1 | — | 1.1 | — |
| 8, - - | 740 | 24.9 | 2.33 | 6.0 | 30,600 | — | 1.0 | 1.0 | — |
| 9, - - | 900 | 20.5 | 1.93 | 6.5 | 26,950 | 0.9 | — | — | 0.9 |
| 10, - - | 850 | 20.7 | 1.95 | 6.5 | 27,300 | 1.2 | — | 1.2 | — |
| 11, - - | 825 | 21.8 | 2.27 | 5.5 | 28,400 | — | 0.9 | 0.9 | — |
| 12, - - | 875 | 20.5 | 2.62 | 4.5 | 26,900 | — | 1.3 | 1.3 | — |
| 13, - - | 800 | 16.4 | 1.76 | 6.0 | 23,000 | — | 0.8 | — | 0.8 |
| 14, - - | 875 | 22.9 | 2.32 | 6.0 | 29,550 | — | 1.1 | 1.1 | — |
| 15, - - | 850 | 20.2 | 1.15 | 11.5 | 26,250 | 0.8 | — | — | 0.8 |
| 16, - - | 900 | 20.5 | 1.30 | 9.5 | 26,650 | 0.9 | — | — | 0.9 |
| Average, | **850** | **22.0** | **2.06** | **6.5** | **29,000** | **0.9** | **1.0** | **1.1** | **0.9** |

* Butter assumed to contain 85 per cent. of butter-fat.

† More or less than 2.2 lbs. *per 1,000 lbs., live weight.*

In the table are summarized the rations fed in the herds studied in the winter of 1893, together with the daily yield of butter during the five days of each test. The animals were of different breeds, and in many ways the conditions were such that the results are not strictly comparable one with the other. In the lack of better data the results are put together in the table to show what light they may throw upon the question of the effect of protein and the nutritive ratio upon the production of butter.

The average daily butter yields are grouped by size of the nutritive ratio of the rations and the weights of protein fed. The animals having the narrower rations produced on the average one-tenth of a pound more of butter per day than those having the wider, and those having the larger amounts of protein gave on the average two-tenths of a pound more of butter per day than those having the smaller quantities of protein. Too much importance should not be attached to these results, as they may have been partly accidental and due to causes other than feed. It is, nevertheless, a noteworthy fact that in the cases in which the cows were in about the same period of lactation, the yields of butter decreased as the protein decreased, and as the nutritive ratio increased. This would seem to indicate that it would be safe in general to feed as much or even more protein than called for by Wolff's standard ration if we would obtain the largest yields of butter from our milch cows. It would also, perhaps, be wiser until we have more light than at present, to make our rations larger, so far as their total energy is concerned, than the German standard. The size of the ration suggested by the Wisconsin Station as a standard ration, when it is measured by its fuel value, may not be too large for the demands of our conditions. Feeding stuffs rich in carbonaceous foods (fats and carbohydrates) are abundant and cheap with us, and it is sometimes difficult to utilize the foods produced on the farm without making a ration larger in total energy than the German standard calls for.

## TESTS OF 1893–94.

In the tests of 1892–93 it is not practicable to compare the cost of production upon narrow and wide rations since the rations differed with different herds. In the winter of 1893–94 tests were made with the same herds on wide and narrow rations, and the financial as well as the physiological results could be observed. The outcome of this work is briefly given here.

Samples of the different feeding stuffs used in the test were taken early in each test and sent to the laboratory for analysis.

As soon as it was possible to obtain the results of the analyses, the ration fed was calculated and suggestions were made for changes in the ration. After changes had been made and the animals had been upon the new ration for a week or longer, the herd was again visited and a new twelve-days' test was made.

The prices of feeding stuffs which are used in calculating cost of the rations fed were current in December, 1893. The manurial value is based upon figures given in the Report of the Massachusetts Agricultural Experiment Station for 1893, pp. 358–365. The nitrogen in the feeding stuff is counted as worth 17½ cents, the phosphoric acid at 5 cents, and the potash at 5½ cents per pound for manure, and it is assumed that 85 per cent. of the quantities in the food may be saved in the manure. Unfortunately most farmers care for manure so poorly that a much smaller percentage is usually saved.

*Valuation of Feeding Stuffs as used in Rations Fed Milch Cows in Winter of 1893–94.*

| Feeding Stuffs. | Market Price per Ton of Feeding Stuffs. | Estimated Value of the Manure Obtainable from One Ton of Feeding Stuffs. |
|---|---|---|
| Wheat bran, - - - - | $19.00 | $13.00 |
| Corn meal, - - - - | 21.00 | 8.00 |
| Cotton seed meal, - - - | 26.00 | 27.00 |
| Cob meal, - - - - | 20.00 | 6.00 |
| Linseed meal, O. P., - - | 30.00 | 22.00 |
| Chicago gluten, - - - | 25.00 | 18.00 |
| Rye meal, - - - - | 21.00 | 8.00 |
| Oat feed, - - - - | 21.00 | 9.00 |
| Corn ensilage, - - - | 2.50 | 1.75 |
| Hay, - - - - - | 18.00 | 6.00 |
| Oat hay, - - - - | 14.00 | 6.00 |
| Corn stover, - - - - | 8.00 | 5.50 |
| Oat straw, - - - - | 10.00 | 6.00 |
| Bog hay, - - - - | 8.00 | 4.50 |

## Herd A.—Tests 18 and 21.

A dairy farm was visited by a Station representative December 4–16, 1893, and after an interval of four weeks it was again visited (January 15–27). There were 19 cows in each test, but four of them were changed between the two tests.

The following discussion includes only the 15 animals entering into both tests. These included 10 Guernseys, 4 Jerseys, and 1 Ayrshire. The average estimated weight was 825 pounds each. The average age was five years. At date of first test the average time since last calf was dropped was five months. None of the cows were within four months of calving. The statistics of the rations fed are summarized in the following table.

The German standard and the ration tentatively suggested on page 46 of this Report and calculated for animals of 825 pounds, live weight, are appended for comparison.

DAIRY HERD A. TESTS 18 AND 21.

*Calculated Per Head of 825 Pounds, Live Weight.*

| Feeding Stuffs. | | | Digestible Nutrients and Fuel Value. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Kind. | | Amount. | Protein. | Fat. | Carbo-hydrates. | Fuel Value. | Nutritive Ratio. | Cost. | Value of Obtainable Manure. | Net Cost. |
| *First Test.* | | Lbs. | Lbs. | Lbs. | Lbs. | Calories | 1: | Cts. | Cts. | Cts. |
| *December 4-16. 12 Days.* | | | | | | | | | | |
| Grain, etc., | Wheat bran, | 5.1 | | | | | | | | |
| | Corn meal, | 3.8 | 1.49 | .45 | 4.63 | 13,300 | 3.9 | 10.4 | 6.4 | 4.0 |
| | Cot. seed meal, | 1.2 | | | | | | | | |
| Hays, etc., | Corn ensilage, | 10.0 | .66 | .37 | 8.94 | 19,450 | 15.0 | 16.2 | 5.9 | 10.3 |
| | Hay, | 16.6 | | | | | | | | |
| Total food, | | **36.7** | **2.15** | **.82** | **13.57** | **32,750** | **7.3** | **26.6** | **12.3** | **14.3** |
| *Second Test.* | | | | | | | | | | |
| *January 15-27. 12 Days.* | | | | | | | | | | |
| Grain, etc., | Wheat bran, | 5.4 | | | | | | | | |
| | Corn meal, | 2.7 | 1.81 | .49 | 4.25 | 13,300 | 3.0 | 10.8 | 7.5 | 3.3 |
| | Cot. seed meal, | 2.2 | | | | | | | | |
| Hays, etc., | Corn ensilage, | 12.6 | | | | | | | | |
| | Hay, | 8.0 | .58 | .33 | 7.32 | 16,100 | 13.9 | 10.9 | 4.4 | 6.5 |
| | Oat hay, | 3.0 | | | | | | | | |
| Total food, | | **33.9** | **2.39** | **.82** | **11.57** | **29,400** | **5.7** | **21.7** | **11.9** | **9.8** |
| German standard, | | — | 2.06 | .33 | 10.31 | 24,400 | 5.4 | — | — | — |
| Standard tentatively suggested, | | — | 2.06 | — | — | 25,600 | 5.6 | — | — | — |

The second ration as fed was larger and hence more expensive than was intended; nevertheless the total cost of the second ration was 5 cents less per head and the net cost was 5½ cents less than the first. The use of cotton seed meal reduces the net cost of the second ration very materially, for the estimated value of the manure obtainable from cotton seed meal equals its cost.

## HERD B.—TESTS 20 AND 23.

Another herd was studied from January 2 to January 14, 1894, and a second test of the same herd was made February 12–24, 1894, after an interval of four weeks.

There were 16 cows in the herd tested, 15 of which were in both tests. These included 10 grade Jerseys and 5 "natives." The average weight of each cow was 750 pounds. The average age was six years, and at time of first test the average time since dropping last calf was three months. None of the cows were within six months of again calving. The rations were as follows:

DAIRY HERD B. TESTS 20 AND 23.

*Calculated Per Head of 750 Pounds, Live Weight.*

| Feeding Stuffs. | | Digestible Nutrients and Fuel Value. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Kind. | Amount. | Protein. | Fat. | Carbo-hydrates. | Fuel Value. | Nutritive Ratio. | Cost. | Value of Obtainable Manure. | Net Cost. |
| *First Test.* | Lbs. | Lbs. | Lbs. | Lbs. | Calories | 1: | Cts. | Cts. | Cts. |
| *January 2-14. 12 Days.* | | | | | | | | | |
| Grain, etc., Cob meal, | 6.2 | .92 | .29 | 4.82 | 11,850 | 6.1 | 9.1 | 3.8 | 5.3 |
| Wheat bran, | 2.9 | | | | | | | | |
| Hays, etc., Oat straw, | 2.2 | .57 | .19 | 6.50 | 13,950 | 12.4 | 9.5 | 5.3 | 4.2 |
| Corn stover, | 8.7 | | | | | | | | |
| Bog hay, | 1.2 | | | | | | | | |
| Oat hay, | 6.3 | | | | | | | | |
| Total food, | **27.5** | **1.49** | **.48** | **11.32** | **25,800** | **8.5** | **18.6** | **9.1** | **9.5** |
| *Second Test.* | | | | | | | | | |
| *February 12-24. 12 Days.* | | | | | | | | | |
| Grain, etc., Cob meal, | 2.5 | 1.47 | .32 | 4.04 | 11,550 | 3.3 | 9.2 | 5.4 | 3.8 |
| Bran, | 4.0 | | | | | | | | |
| Gluten meal, | 2.3 | | | | | | | | |
| Hays, etc., Oat straw, | 1.8 | .54 | .18 | 6.12 | 13,150 | 12.2 | 9.1 | 4.9 | 4.2 |
| Corn stover, | 7.3 | | | | | | | | |
| Bog hay, | 1.2 | | | | | | | | |
| Oat hay, | 6.9 | | | | | | | | |
| Total food, | **26.0** | **2.01** | **.50** | **10.16** | **24,700** | **5.7** | **18.3** | **9.3** | **9.0** |
| German standard, | — | 1.88 | .30 | 9.38 | 22,200 | 5.4 | — | — | — |
| Tentative standard, | — | 1.88 | — | — | 23,250 | 5.6 | — | — | — |

In both rations coarse fodders are largely used. These make the rations cheaper than if good hay had been used. The use of these hay substitutes is to be commended, although they necessitate the use of concentrated foods rich in protein. The ration as

fed in the first test was a low cost one, and it would be difficult to furnish the needed grain feed at much lower cost. The assumed value of the coarse fodders is probably higher than they would bring in market; and their use in this way disposes of them at a good price.

### Herd C.—Tests 22 and 25.

A herd of 16 cows was studied from January 29 to February 10, 1894, and after an interval of four weeks another 12-days' test of the same herd was made, March 5–17. Fourteen of the cows were in both tests. These included 6 grade Jerseys, 2 grade Durhams, and 6 "natives." The average weight of the cows was 725 pounds. The average age was five years and, at the date of the first test, the average time since dropping the last calf was six months. With one exception none were within three months of being due to calve again. The rations were as follows:

DAIRY HERD C. TESTS 22 AND 25.

*Calculated Per Head of 725 Pounds, Live Weight.*

| Feeding Stuffs. | | Digestible Nutrients and Fuel Value. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Kind. | Amount. | Protein. | Fat. | Carbohydrates. | Fuel Value. | Nutritive Ratio. | Cost. | Value of Obtainable Manure. | Net Cost. |
| *First Test.* | Lbs. | Lbs. | Lbs. | Lbs. | Calories | 1: | Cts. | Cts. | Cts. |
| *Jan. 29–Feb. 10. 12 Days.* | | | | | | | | | |
| Grain, etc., { Cob meal, - | 4.3 | .77 | .21 | 3.66 | 9,150 | 5.4 | 7.2 | 3.3 | 3.9 |
| Grain, etc., { Wheat bran, - | 3.0 | | | | | | | | |
| Hays, etc., { Stover, - | 3.5 | .61 | .20 | 5.41 | 12,000 | 9.6 | 12.2 | 3.6 | 8.6 |
| Hays, etc., { Oat hay, - | 3.9 | | | | | | | | |
| Hays, etc., { Hay, - | 4.5 | | | | | | | | |
| Total food, - | **19.2** | **1.38** | **.41** | **9.07** | **21,150** | **7.3** | **19.4** | **6.9** | **12.5** |
| *Second Test.* | | | | | | | | | |
| *March 5–17. 12 Days.* | | | | | | | | | |
| Grain, etc., { Cot. seed meal, | .4 | 1.16 | .29 | 3.67 | 10,200 | 3.8 | 8.1 | 4.2 | 3.9 |
| Grain, etc., { Linseed meal, | .4 | | | | | | | | |
| Grain, etc., { Chicago gluten, | .4 | | | | | | | | |
| Grain, etc., { Cob meal, - | 4.0 | | | | | | | | |
| Grain, etc., { Wheat bran, - | 2.6 | | | | | | | | |
| Hays, etc., { Hay, - | 5.9 | .64 | .22 | 5.42 | 12,200 | 9.4 | 9.7 | 3.7 | 6.0 |
| Hays, etc., { Oat hay, - | 6.3 | | | | | | | | |
| Total food, - | **20.0** | **1.80** | **.51** | **9.09** | **22,400** | **5.7** | **17.8** | **7.9** | **9.9** |
| German standard, - | — | 1.81 | — | 9.06 | 21,450 | 5.4 | — | — | — |
| Tentative standard, - | — | 1.81 | .29 | — | 22,500 | 5.6 | — | — | — |

The second ration cost a cent and a half a head less than the first, and taking the manurial value into account there is a saving of 2½ cents per day in net cost of food. The second ration agrees very closely with the tentatively suggested standard ration.

These six tests with three herds are summarized in the following table:

*Summary of Daily Rations Fed, and Daily Milk and Butter Yield from Three Herds with a Wide and a Narrower Ration.*

| Herd. | Average Weight of Cows. | No. of Test. | Daily Ration Per Head.* Digestible Protein. | Fuel Value of Digestible Nutrients. | Nutritive Ratio. | Total Cost. | Net Cost.† | Average Daily. Milk Flow. | Yield of Butter.‡ | Cost of Food to Produce. 100 lbs. Milk. Total Cost. | Net Cost.† | 1 lb. Butter. Total Cost. | Net Cost.† |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lbs. | | Lbs. | Calories | 1: | Cts. | Cts. | Lbs. | Lbs. | $ | Cts. | Cts. | Cts. |
| A, - | 825 | 18 | 2.15 | 32,750 | 7.3 | 26.6 | 14.3 | 18.1 | 1.07 | 1.47 | 79 | 25 | 14 |
| | | 21 | 2.39 | 29,400 | 5.7 | 21.7 | 9.8 | 18.9 | 1.09 | 1.15 | 52 | 19 | 9 |
| B, - | 750 | 20 | 1.49 | 25,800 | 8.5 | 18.6 | 9.5 | 18.1 | .87 | 1.00 | 53 | 21 | 11 |
| | | 23 | 2.01 | 24,700 | 5.7 | 18.3 | 9.0 | 17.9 | .89 | 1.03 | 50 | 20 | 10 |
| C, - | 725 | 22 | 1.38 | 21,150 | 7.3 | 19.4 | 12.5 | 13.7 | .65 | 1.41 | 91 | 30 | 19 |
| | | 25 | 1.80 | 22,400 | 5.7 | 17.8 | 9.9 | 13.6 | .69 | 1.30 | 73 | 26 | 14 |
| D.§ | 825 | – | 2.06 | 25,600 | 5.6 | — | — | — | — | — | — | — | — |
| | 750 | – | 1.88 | 23,250 | | | | | | | | | |
| | 725 | – | 1.81 | 22,500 | | | | | | | | | |

* These rations are given in detail on pages 31, 35–36, 38 and 50–52.
† Total cost less value of the obtainable manure.
‡ Butter assumed to contain 85 per cent. butter-fat.
§ Tentatively suggested standard ration.

## THE EFFECT OF NARROW RATIONS ON MILK FLOW AND BUTTER YIELD.

At the time of the second test in each case the cows were six weeks farther along in the period of lactation and would in consequence have naturally reduced their milk flow and butter yield. It is impossible to say exactly how much this natural shrinkage would have been. In animals as near calving as some of these were the shrinkage would have probably been large, while in the case of the cows in "flush" the decrease would have been less marked. From a record of a herd of native cows and Ayrshires extending over 15 years, including 83 different animals and 210 calvings, the New York Experiment Station* concluded that "the natural falling off in milk for each month from calving

* Annual Report New York Agricultural Experiment Station, 1886, pp. 21-23.

is about 9 per cent. of the yield of the preceding month." The shrinkage in butter yield would, of course, be less, because the milk grows richer in fat.

In the case of herd A, instead of a falling off in milk flow there was an average daily increase of seven-tenths of a pound in the test while they were fed the narrow ration over what it had been with the wide ration six weeks earlier. There was practically no change in milk flow in the case of the two other herds. With all three herds there was a slight increase in butter yield with the narrow ration in the second test. The total size of the ration as measured by the fuel value averaged less in the second test than in the first. The protein was increased and the carbohydrates and fats were decreased in the second test.

In these cases both milk flow and butter yield were so much affected by the change from a wide to a narrow ration that instead of a shrinkage in production, as would naturally follow from advancement in period of lactation, the animals more than held their own. Too much importance should not be given to a few results, but these are in line with the best observations here and elsewhere, that so far as physiological effects are concerned, narrow (nitrogenous) rations give larger yields of both milk and butter than do wide (carbonaceous) rations.

COST OF MILK PRODUCTION WITH WIDE AND NARROW RATIONS.

The following tabulations indicate that the cost of milk and butter production from the food alone was much less on the narrow ration, even when the cows were six weeks farther advanced in lactation than earlier on the wide ration. So far as these tests may be taken as an indication, narrow rations may be fed more profitably than wide.

The cost of food to produce 100 pounds of milk was as follows:

| Herd. | Total Cost of Feed. | | Net* Cost of Feed. | |
|---|---|---|---|---|
| | Wide Ration. | Narrower Ration. | Wide Ration. | Narrower Ration. |
| A, - - - - - | $1.47 | $1.15 | $0.79 | $0.52 |
| B, - - - - - | 1.00 | 1.03 | .53 | .50 |
| C, - - - - - | 1.41 | 1.30 | .91 | .73 |
| Average, - - | **$1.29** | **$1.16** | **$0.74** | **$0.58** |

* Total cost less value of obtainable manure.

The cost of food to produce one pound of butter was as follows:

| Herd. | Total Cost of Feed. | | Net* Cost of Feed. | |
|---|---|---|---|---|
| | Wide Ration. | Narrower Ration. | Wide Ration. | Narrower Ration. |
| | *Cents.* | *Cents.* | *Cents.* | *Cents.* |
| A, - - - - - | 25 | 19 | 14 | 9 |
| B, - - - - - | 21 | 20 | 11 | 10 |
| C, - - - - - | 30 | 26 | 19 | 14 |
| Average, - - | 25 | 22 | 15 | 11 |

* Total cost less value of obtainable manure.

In 1893 we visited a dairy farm on which the cows (a herd of grade Jerseys) were receiving a very wide ration. The ration as fed contained per 1,000 pounds, live weight, only 1.35 pounds digestible proteïn. The nutritive ratio was 1 to 11.3. In 1894 we again visited this farm, intending to make a 12-days' test with the old method of feeding and later another test with a narrow ration. But it transpired that the owner had meanwhile caught the idea himself and had changed his feeding practice very materially. We made a 12-days' test and found that instead of a wide ration he was feeding a narrow one, and one that we had not the hardihood to attempt to improve. He was feeding 2.70 pounds digestible protein per 1,000 pounds, live weight, or double the amount of the year before, and the nutritive ratio was 1 to 5.7 instead of 1 to 11.3. The gross cost of the ration for 1893 was 23 cents per 1,000 pounds, live weight, and in 1894, 22 cents. The net cost in 1894 was 9 cents against 13 cents in 1893. The average weight of the herd was practically the same both years. The 5-days' test of 1893 and the 12-days' test of 1894 compare as follows:

| Total Cost of Food to Produce | | | | Net* Cost of Food to Produce | | | |
|---|---|---|---|---|---|---|---|
| 100 Lbs. Milk. | | 1 Lb. Butter. | | 100 Lbs. Milk. | | 1 Lb. Butter. | |
| Wide Ration. | Narrow Ration. | Wide Ration. | Narrow Ration. | Wide Ration. | Narrow Ration. | Wide Ration. | Narrow Ration. |
| *1893.* | *1894.* | *1893.* | *1894.* | *1893.* | *1894.* | *1893.* | *1894.* |
| $1.44 | $1.08 | 24 cts. | 19 cts. | 81 cts. | 51 cts. | 14 cts. | 9 cts. |

* Total cost less value of obtainable manure.

It would be difficult to convince this man that it did not pay him to change from a wide to a narrow ration.

## SUMMARY.

*In the winter of 1892–93, the Station began making systematic observations of the winter feeding practices of Connecticut dairymen. The chief points upon which information was obtained were: Number of animals in the herd; breed, age and approximate weight of each cow; length of time since dropping last calf and till due to calve again; weights of milk flow; percentages and amounts of butter-fat in the milk; kinds, weights and chemical composition of feeding stuffs used.*

*In 1892–93 sixteen herds were visited and a five-days' test made with each. In 1893–94 six herds were visited, and in four instances the time of study of the management and products of each were extended to twelve days. As soon as the analyses could be made the rations were calculated, and in three cases other rations were suggested. The feed was gradually changed to the suggested ration, and after four weeks from the close of the first test another twelve-days' test was made with the new ration.*

*In general there was the largest yield of milk and the largest butter production with narrow rations rich in protein. Wide rations, low in protein, did not in these instances favor large milk or butter production.*

*In the three tests of 1893–94, when it was possible to study the financial side of the feeding, narrow rations, rich in protein were decidedly the more economical.*

*Bearing in mind that there is no such thing as a "best ration," and that all attempts to express in terms of protein and energy the needs of a dairy cow are only approximations, the following ration is tentatively suggested as a basis for feeding dairy cows:*

*Organic matter, 25 pounds; digestible protein, 2.5 pounds, and enough digestible fat and carbohydrates to bring the fuel value up to about 31,000 Calories.*

*The subject of cattle feeding and handling is a large one, and only general principles can be laid down. No hard and fast rules for feeding are now known, and doubtless none ever will be known. It is nevertheless true that the man who exercises the greatest amount of good judgment, based upon all that the most advanced science can bring to him, and who tries to put into practice the knowledge thus acquired, will be much surer of success than one who works blindly. There may be no "best" breed, no "best" ration, and no "best" way of handling dairy stock, but there are poor cows, uneconomical rations, and bad ways of handling, and the man who learns to avoid the bad and choose the better is well on the road toward the best.*

# BACTERIA IN THE DAIRY.*

BY H. W. CONN.

## VI. EXPERIMENTS IN RIPENING CREAM WITH BACILLUS NO. 41.

In Bulletin No. 12 of this Station was published the result of a series of experiments that had been carried on in the laboratory upon the subject of the ripening of cream. In that Bulletin there were mentioned a series of preliminary experiments with *Bacillus No. 41*, which gave most promising results as an organism for artificial ripening of cream in butter-making. During the whole of the past year, further experiments have been carried on with this organism in a variety of places, with results which are extremely satisfactory and promise to be of much practical importance. The experiments with the organism have been so satisfactory that a more careful description of the organism itself and a more complete account of the experiments with it appear to be needed, and the present article, therefore, is designed to give these details.

The original culture of *Bacillus No. 41* was obtained from a lot of milk which had been sent to the Columbian Fair at Chicago among the food exhibits. It was said to be "preserved," but had not been thoroughly sterilized and had become bitter. There had developed in the milk a number of organisms which were isolated by Mr. W. M. Esten, who had charge of the biological exhibit, and among them *Bacillus No. 41* was found. The characteristics of this organism are as follows:

*Locality.*—Milk from Uruguay.

*Morphology.*—A bacillus occasionally clinging two together but never forming chains. Size 1.1 $\mu$. by 6 $\mu$. When growing in potato it is slightly longer than in agar. No spores.

*Motility.*—Non motile.

* During the past seven years investigations on the Bacteria of Milk have been conducted in behalf of the Station by H. W. Conn, Professor of Biology in Wesleyan University. Some of the results have been given in the publications of the Station, as follows: *Bacteria in Milk, Cream, and Butter*, Bulletin 4, and Annual Report for 1889, pp. 52–67. *Ripening of Cream*, Annual Report for 1890, pp. 136–157. *A Micrococcus of Bitter Milk*, Report for 1891, pp. 158–162. *The Isolation of Rennet from Bacteria Cultures*, Report for 1892, pp. 106–126. *The Ripening of Cream by Artificial Cultures of Bacteria*, Bulletin 12 and Report for 1893, pp. 43–68. See also *The Fermentations of Milk*, Experiment Station Bulletin No. 9 of the Office of the Experiment Station of the U. S. Department of Agriculture.

*Relation to air.*—Will not grow under mica plate.

*Temperature.*—Grows best at about 20–23° C.; at 35°, scarcely any growth;* killed by temperature of 60° C. to 10 minutes.

*Colony on Gelatine.*—A smooth, round colony under surface. On surface a small, grey, raised bead-like colony, spreading somewhat, reaching size of 1 mm. occasionally. Not characteristic.

*Gelatine Stab Culture.*—Slight needle growth. Spreads over surface as a moist, white, thick mound, forming a nail growth. Does not liquefy.

*Agar-Agar.*—An abundant, white, smooth, glistening layer.

*Potato.*—Raised, thick, whitish or slightly yellow-tinged layer. Differing in color with amount of moisture. When very moist, is white, but when dry tends to a yellowish tinge. Grows profusely.

*Milk.*—Does not curdle either at 20° or 35°. After two to three weeks becomes slightly translucent and brownish. The reaction is slightly acid. After three to four weeks it seems to digest into a translucent mass. It acquires a pleasant aroma.

*Bouillon.*—Very cloudy with heavy scum. After five days scum sinks and forms a sediment. Liquid remains cloudy after a month's growth.

From the above description it will be noticed that the organism, while forming an acid in its growth in milk, is not to be regarded as one of the milk-souring organisms. Milk under its influence becomes acid, but the acid production is quite slight and the milk, under no condition, becomes curdled. Even when growing at a warm temperature the milk remains limpid for weeks, finally becoming somewhat brownish. After cultivation of the organism for a year or more in the laboratory, its acid-producing powers seem to be somewhat greater than at first.

This organism has proved the best of all of the many species of bacteria thus far studied in its effect upon cream in ripening. Preliminary experiments with the organism have already been described, and by reference to Bulletin 12 of this Station it will be seen that those experiments, both in the laboratory with small lots of butter and in a neighboring creamery, gave promise of the possibility of the production of an excellent butter. The further continuation of those experiments from the time of the publication of Bulletin 12 will be now described.

## METHOD OF EXPERIMENT.

It may be well first to explain the method of experiment which has been found after considerable trial to be, all things considered, the most satisfactory. Thus far the organism has been

* After a year's cultivation it failed to grow at 35°, although would do so feebly when first studied.

cultivated solely in the writer's bacteriological laboratory and upon ordinary culture media.

When experiments in the creamery or elsewhere are desired, the procedure is as follows: There is first placed in an ordinary flask a half pint of milk, and this is sterilized by discontinuous steaming for three or four successive days. This sterilized milk is inoculated with a small amount of the *Bacillus No. 41*, and the culture thus made is allowed to grow at about 23° C. (74° F.) for a couple of days. The object of this growth is merely to increase the number of bacteria and thus make a larger inoculation in the creamery possible. After two days' growth the culture is sent to the creamery and the rest of the experiment is performed there by the butter-maker.

A lot of cream, amounting to six or eight quarts, is placed in a metal vessel and pasteurized, by being put into a tub of water into which steam is allowed to run. The temperature of the cream is allowed to rise to about 69° C. (156° F.) and to remain there for some ten minutes. The cream vessel is then removed and placed in cold water and cooled as rapidly as possible. When the temperature has fallen to about 23° C. (74° F.) the milk culture of the bacillus above described is poured into it and is thoroughly mixed with it by stirring. The vessel is then covered and placed in the ripening room of the creamery for two days, at the end of which time the cream is churned and the buttermilk reserved for further use. The object of this ripening of a lot of six quarts of cream is to increase the number of bacteria in order that a large and strong culture may be obtained for use in the large vat of cream in the creamery. The buttermilk from the churning of the six quarts of cream is then inoculated into the day's cream as soon as the cream is placed in the vat for ripening. The cream in the large vat receives no preliminary treatment, the prepared milk being poured into it directly. The cream is then allowed to ripen at a normal temperature for about twenty-four hours and churned as usual. Before the churning two or three gallons of the ripened cream is set aside to be added to the next day's cream collection to insure a continuation of the process. In this way the ripening is continued day after day, a small amount of each day's churning being set aside for the next day's inoculation, and the process is continued as long as the good effects of the original culture are seen. In the series of experiments which were instituted it was

found that the effect of the first culture could be kept up in this way from three to six weeks, after which a new pure culture from the bacteriological laboratory was needed.

It will be noticed in these experiments that in practical use the cream of each day's gathering is not pasteurized nor treated in any way to insure removal of the bacteria which chance to be in it. It may seem strange that under these conditions the addition of a pure culture would have decided effect upon the ripening of the cream. The explanation of the matter seems, however, to be simple. As is well known, a properly ripened cream needs to be slightly acid in order to give the flavor which is usually desired. Now *Bacillus No. 41* does not produce sufficient acid to give this flavor, and in laboratory experiments with strictly pure cultures upon pasteurized cream it is found that the flavor of the butter is somewhat too flat. The cream as is ordinarily collected for the creamery contains organisms which render it acid, and when, therefore, *No. 41* is added to the ordinary cream the effect of this culture is enhanced by the acid produced by the organisms already present. There is thus obtained a cream which is acid and also influenced by the peculiar effects of *No. 41*. Moreover, the culture bacteria were always added in excess. By cultivating as above described for several days in larger lots of cream, and by adding to the day's collection of cream two or three gallons of buttermilk or ripened cream, the number of bacteria of *Bacillus No. 41* added to the lot of cream was so great that their effects were plainly noticeable, in spite of the presence of the other species of bacteria which were in the cream as originally collected.

## RESULTS OF THE INOCULATION.

In a long series of experiments the effect of the method of inoculation above described was always uniform and as follows: The first lot of cream, six or eight quarts, gave a butter which was moderately good, containing a somewhat pleasant flavor, but not quite the typical flavor desired. The first churning in the large lot of butter from the ordinary cream vat gave butter slightly superior to that in the small churning. Then, on each day for several successive churnings, the quality of the butter improved. For perhaps one or two days it was a little difficult to say that the artificial culture had produced much of an improvement, the butter having about its ordinary flavor. But after

two or three days there began to be noticed a pleasant *added* flavor which was not there at first, and after several days' churning this added flavor became very pronounced and noticeable to all who examined the butter. This delicate, exquisite flavor now continued and remained in the butter of each day's churning for some time, the length of time varying with, at present unknown, conditions. If the flavor began to deteriorate it could be immediately restored by the addition of a new culture from the laboratory by the same method above described, and there is thus no difficulty in constantly maintaining this flavor in the butter.

The general results in the creamery at Cromwell where most of these experiments have been performed, have been as follows: The experiments began in November, 1893, and there was noticed an immediate improvement in the butter. These experiments have been continued constantly with the exception of the months of July, August and September, until the present time and with uniform results. During this time pure cultures have been sent to the creamery upon many different occasions and have been used according to the above method. In each case there was an improvement in the butter, and the experiment was continued for three, four, five or six weeks, until the butter-maker noticed a distinct deterioration in the quality of his butter. Then a new culture was sent to the creamery which immediately restored the quality to the butter.

At four distinct periods the butter from the creamery was sent to an expert for rating, together with a lot of butter made from half of the same cream of the same day, but without the artificial inoculation. In *every case* where the butter was thus sent the butter made by the artificial culture was rated higher than the butter made without it. It was marked from four to fifteen points on a scale of 100, ahead of the normal butter, the improvement being chiefly in the flavor. In one case the inoculated butter was 18 points ahead of the uninoculated butter. In another case three lots were sent to the expert, one made with a culture of *Bacillus No. 41*, a second made with the artificial culture sold by Carl Hansen's dairy company, and a third lot by a combination of *Bacillus No. 41* and Carl Hansen's ferment. The butter made from *Bacillus No. 41* rated highest, 95 points, the combination next 83 points, and Carl Hansen's lowest. In addition to the rating by the butter expert the butter was in all

cases carefully examined by individuals who were more or less connoisseurs of proper butter flavor, and in each instance the butter made by the artificial culture was rated as better than that made without such culture. In most of these tests the individual examining the butter had no knowledge of the experiment.

Perhaps the most satisfactory experiment of all was one made early in June. June butter, as is well known, is in flavor about the best that is produced during the year, and the effect of *Bacillus No. 41* upon June butter was therefore especially interesting. Early in June, when the amount of cream collected by the creamery was very large, two large vats full of cream were collected. One of these was inoculated with *No. 41* and the other was uninoculated. They were then both allowed to stand in the same room at the same temperature for the same length of time to ripen, and were subsequently churned. The effect of *No. 41* even here was exceptionally striking. Both lots of cream produced, as was to be expected, an excellent quality of butter, but *No. 41* had an aroma more pronounced and more agreeable than that of the butter made without the inoculation. In both taste and odor the butter made by inoculation was decidedly superior to that made without it. This butter was submitted for testing to a large number of persons, and no one had the slightest hesitancy in deciding that *No. 41* made the superior quality of butter. It was most strikingly noticed just as soon as the wrapper was taken from the butter, the pleasant aroma of the inoculated butter filling the nostrils at once, while the uninoculated butter did not possess this decidedly pleasant aroma and taste.

The general result of experiments thus carried on now for at least twelve months in the Cromwell creamery, has been that this artificial culture uniformly improves the value of the butter. The effect of the pure culture is seen best after two or three days' ripening, and lasts from three to six weeks, but by the constant use of the culture it may be kept up indefinitely.

Mr. E. D. Hammond, the superintendent of the Cromwell creamery, has put in my hands the following letter, indicative of the experiments carried on in his creamery:

*H. W. Conn:* December 20, 1894.

MY DEAR SIR:—In reply to yours of the 19th I will say that we have used your culture the past year, with the exception of the summer months when you were away and we could not get it. There can be no doubt as to its producing

butter of a superior and uniform quality. In every instance where we have taken a quantity of cream, thoroughly mixed, and divided it into two parts, and have treated one in the usual way and have inoculated the other with the culture, and have sent the product to an expert to be judged, the culture has scored the highest. It produces a fine, sweet flavor which leaves a most pleasing taste in the mouth. For the sweet butter trade it is decidedly superior.

Yours truly, E. D. HAMMOND.

It was, of course, desirable that these results should be confirmed in other places, and for this reason the culture has been used in several localities. These experiments have been as follows:

One lot of the culture was sent to Mr. George M. Whitaker of West Dudley, Mass. The creamery of which he is president was making at the time the highest quality of butter, which commanded a very high price in the Boston markets. The culture sent was broken in the journey and only a small amount of it reached the creamery. It was, however, used by Mr. Beck, the butter-maker of the creamery, and his statement was that he noticed a decided improvement in the quality of his butter as the result of it. Owing to the distance and the consequent difficulty of furnishing the culture at this creamery the experiments were not continued, only one churning being made with the culture.

A culture of the bacteria was sent to Mr. Hollister Sage, superintendent of the creamery at Stepney Depot, Conn. The culture sent to this place for necessary reasons, was not a culture in milk, but an ordinary bacteria culture on agar-agar, and required the use of certain bacteriological methods in its practical application to cream. Mr. Sage, however, seemed to have no difficulty in making use of it as directed and reported, after the proper length of time, that he had noticed a decided and pleasant flavor to his butter, which was not there before and which gave it an enhanced value. Several months later a second culture was sent him in a different form, but no report from it has yet been received.

Up to this point the experiments had been practically confined to Middletown and the immediate vicinity. It was of course very desirable that they should be repeated in other localities and by other persons, in order to determine whether the effect was local only, and to what extent other creameries besides the Cromwell creamery, would be benefited by the use of *Bacillus No. 41.*

During the last three months therefore, arrangements have been made by which the organism has been used in other States. These experiments have now been made in the State of Indiana, in the creamery of R. W. Furness, Indianapolis. In Pennsylvania the organism has been introduced into some thirty-five different creameries through the assistance of Mr. John Jamison, a large commission merchant of Philadelphia. In Iowa it has also been introduced into twenty-eight creameries controlled by Wm. Beard & Sons, commission merchants in Decorah, Iowa. The experiments in this large number of creameries have been most rigid. In many cases a lot of cream has been divided into two portions, one of which has been inoculated and the other not, the resulting butter being compared carefully. In some instances the organism has been inoculated into old cream which had acquired considerable of an odor by standing. In several instances it has been used in creameries in which the quality of the butter has not been first-class, and in others it has been used in creameries of the highest grade, whose butter commanded high market prices. In two instances it has been used in creameries which were at the time troubled with an undesirable flavor due to what is known as "frost weed." The butter made in the various creameries has been submitted for testing to experts, who in some cases knew of the experiments, and in others knew nothing of them. The butter made by the use of the culture was kept in the creamery side by side with the ordinary butter to test its keeping property. In short, the greatest variety of tests have been tried in this large series of creameries to determine whether the organism really possesses in other localities the valuable property that it has appeared to possess in the experiments conducted in Connecticut.

The results of these experiments have been highly satisfactory and to me somewhat surprising, in spite of my belief in the value of the organism in butter-making. With a single exception none of this large series of creameries has failed to report an improvement in their butter. The creamery which did not find such improvement was reported as failing to have proper care for cleanliness in its butter-making process, and the failure to find an improvement has not therefore been thought to be significant. All other creameries in this large number of over sixty have found an improvement in their butter, sometimes appearing at once, and in other cases appearing after a few days use of the

artificial inoculation. In private letters mentioning the experiments Mr. Furness says: "The indications are that there is a decided improvement in both the keeping qualities and the flavor of the butter." Mr. S. F. Doolittle, a commission merchant in Indianapolis, says: "There is a decided improvement in the butter made with the culture over the butter made *with the same cream* without the culture. The butter made with the culture has a 'grass flavor.'" Mr. Jamison says: "We feel satisfied that the butter from any creamery can be improved to such an extent that the butter will bring from two to three cents per pound more on its merits than before using the culture." Wm. Beard says: "I consider this Bacillus the greatest discovery known for producing a high and uniform flavor in butter. We also believe it will greatly increase the keeping qualities of the butter."

The value of this testimony from such widely separate sources is evident at once. It shows two things especially. First, that the effect of *Bacillus No. 41* in improving butter is not confined to Connecticut or New England; and second, that the effect is not imaginary upon the part of those interested in the experiments in this Station. Each of these creameries in which the experiments have been begun has continued the use of the artificial inoculation, and all are using it at the present time of writing. When creameries in Connecticut, Iowa and Pennsylvania all alike report a decided improvement in the butter, we are justified in concluding that *Bacillus No. 41* has the power of adding to butter a desirable flavor in widely separated localities under different conditions and as determined by different experts.

When these experiments were begun it was doubted whether the use of the culture in private dairies would be practicable. The long period during which the cream is being collected frequently makes the cream four or more days old before it is churned. It is quite possible that the growth of the ordinary cream bacteria would be so great in this interval as to interfere with the action of the artificial culture. The first experiment of the kind was performed in a dairy in the vicinity of Middletown. Mr. F. T. Kurt told me in June that in his creamery they had been having trouble with the appearance of "curds" in the butter, a difficulty with which every butter-maker is more or less familiar. This trouble had been proving a great nuisance

in the dairy and had continued in spite of their attempts to get rid of it. He wanted to know if it was possible that a culture of *Bacillus No. 41* might improve his butter. He was told that it was doubtful if the culture would have much effect upon the curds, but that it might perhaps improve the butter. He therefore obtained a culture and used it in accordance with the above method and reported an immediate and a striking improvement in the butter. The curds disappeared in the butter that was ripened by the artificial culture, and every one to whom the butter was submitted stated that it was decidedly superior to the butter that had been made previously. The experiments were not continued in this dairy for any length of time, and the butter immediately fell off again in quality. The following letter indicates the experience of Mr. Kurt:

*Dr. H. W. Conn:*

DEAR SIR:—During the early summer, at a time when the quality of butter ought to have been at its best, the butter made in our dairy was very bad. In spite of every precaution in the ripening of the cream and in working the butter, there appeared streaks of curd which increased in standing, so spoiling the butter for market.

Acting on your suggestion I ripened a portion of cream with your butter culture and allowed another part to ripen as before. Two churnings were made with the following results: The part ripened with your culture yielded butter of exceptionally fine grain, and the streaks of curd had entirely disappeared; moreover, there was a marked improvement in the flavor of the butter. The part that was ripened by itself contained the curd and was of inferior quality.

Yours truly,
FRANKLIN T. KURT.

A second experiment was in the dairy of Mr. A. B. Caswell of Ashby, Mass. Mr. Caswell had been having complaints from his patrons in regard to the butter that he had been furnishing them, and requested a trial of the *Bacillus No. 41* upon his butter. A culture was furnished him in the same manner as in other experiments and he made the butter in the ordinary way. The two lots of butter which were made, one from the artificially ripened cream and the other from the normally ripened cream, showed a decided though not great difference. Both were an excellent flavored butter, but the one made from the artificial culture had in addition to the ordinary flavor the usual pleasant aroma and taste which has been found elsewhere with *Bacillus No. 41*.

The third experiment in a private dairy was on the farm of Mr. Walter Laws, Westminster, Mass. Mr. Laws had a private

dairy in which he made butter of a very high grade. In the month of September he obtained the first premium in a county fair which was held in Fitchburg, Mass. Knowing of these experiments, however, he wished to try the effect of *Bacillus No. 41* upon his butter, and a culture was furnished him and used in the usual manner. The report which he subsequently sent me was that his butter was decidedly improved by the use of the artificial culture. He continued the use of the culture for several weeks, believing that he obtained a better butter thereby. In a letter written subsequently he informed me that his butter, during the period of the use of the culture, had been better than was common at that season of the year, though whether to attribute it to the culture or to the food eaten by the cows, he did not know.

So uniform have been the results of the use of this organism that it must be regarded now as beyond the reach of experimentation, and *Bacillus No. 41* takes its rank as a species of organism whose artificial use in the ripening of cream will produce a striking improvement in the flavor of the butter. The effect of the culture upon the various grades of butter is not exactly what might have been expected, and I have been considerably surprised thereby. When the experiments were begun I had supposed it probable that the use of the artificial culture might improve a poor quality of butter, but was very doubtful whether it would have any effect, at least any advantageous effect, upon first-class butter. Experiments, however, have shown that the organism appears to be of decided value even in first-class creameries. As already mentioned, the effect of the organism appears to be to *add* to the butter an especially delicate aroma and taste, and this delicate aroma and taste is added equally to butter of a poor grade and medium grade, or to butter of the very highest quality. In the light of the present experiments, therefore, it appears that all grades of butter may be somewhat improved by the use of artificial cultures.

Another matter of some interest is the fact that *Bacillus No. 41* is not a milk-souring organism. The "ripening" of cream is in many places called the "souring" of cream, and it has been supposed by all experimenters hitherto that the souring was identical with the ripening. For this reason all of the species of bacteria which have hitherto been used in ripening cream have been acid producing organisms. Experimenters have not thought

it worth while to investigate whether or not the aroma of butter might not be due to species of organisms that do not normally sour the cream. *Bacillus No. 41*, while it produces a very slight acid reaction, does not sour the cream, and it belongs, therefore, to an entirely different class of organism from those hitherto used. This is especially interesting as indicating that probably the aroma of the butter is entirely distinct from the souring of the cream and may be produced either by acid organisms or by organisms that do not produce acid.

In one other respect *Bacillus No. 41* appears to show itself as decidedly more advantageous in practical use than the organisms hitherto used. As will be seen above no previous treatment of the cream is needed in order that *Bacillus No. 41* may produce its appropriate results. This, of course, greatly simplifies the use of the organism and makes it much more probable that artificial inoculation of cream for ripening may in the future become a somewhat universal process. So long as butter-makers are obliged to heat their cream before artificial inoculation, in order to destroy bacteria already present in it, so long will they hesitate about adopting any form of artificial inoculation. When, however, the butter can be improved from three to eighteen points by the simple addition of a culture of the proper species, the use of the organism becomes decidedly easier. When first undertaking these experiments I was extremely incredulous as to the likelihood that artificial ripening of cream would ever be very common among butter-makers. Having, however, seen what good results can accrue to all grades of butter by the simple addition of a culture to the cream, I am now prepared to believe that the artificial ripening of cream will have a growing popularity among the butter-makers of this country.

## SUMMARY.

*The results of the experiments with Bacillus No. 41 bring out three points of especial importance.*

*Bacillus No. 41 is not to be regarded as a cream-souring organism, but one whose value in ripening cream depends upon its power of adding desirable aroma to the butter.*

*In the use of Bacillus No. 41 no previous treatment of the cream to be ripened is necessary before it is inoculated with the culture.*

*Up to the present time experiments in at least sixty creameries and with some hundreds of thousands of pounds of butter have resulted in uniform improvement in the quality of the butter made from cream ripened with Bacillus No. 41.*

# BACTERIA IN THE DAIRY.

## VII. SOME OBSERVATIONS OF THE NUMBER OF BACTERIA IN DAIRY PRODUCTS.*

BY A. E. LOVELAND AND W. S. WATSON.

### NUMBER OF BACTERIA IN MILK.

Within the last few years, with the improvement of methods and the discovery that milk may serve as the medium for transporting pathogenic (disease) germs, new interest has been aroused in the bacteriological study of milk. It has been found that the milk from a perfectly healthy cow, when entirely uncontaminated, is absolutely sterile, *i. e.*, contains no germs. But ordinary milk always contains bacteria, and as milk furnishes an excellent food medium for their development, they multiply very rapidly. The presence of a large number of germs does not necessarily imply that the milk is injurious, nor does a small number of germs prove that the milk is harmless. It is not the *number* but the *character* of the germs which determine their harmfulness. It is quite possible that milk containing very large numbers of bacteria may be entirely free from harmful species, while, on the other hand, milk with only a small number of bacteria may contain disease germs.

A small number of germs may be considered as evidence of two conditions of the milk. First, it has been handled cleanly, *i. e.*, not much stable dirt has entered the pail during the process of milking, and the probability is that the milk dishes were carefully scalded; second, it may be evidence of freshness, for if the milk had stood many hours the number of bacteria would be quite large, unless the temperature of the milk is lowered so they cannot grow. With these facts in mind it will be more easily understood why milk in large cities, where it is frequently forty-eight hours old when delivered, shows large numbers of bacteria.

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* These investigations were made in the Bacteriological Laboratory of Wesleyan University under the direction of Prof. Conn.

## EUROPEAN INVESTIGATIONS.

In the winter of 1888–89 Dr. J. Clauss worked on the milk in Würzburg and found that the number of germs in a cubic centimeter of milk ranged from 222,000 to 2,300,000. The average was between one and two millions per cubic centimeter.*

During the same winter Knopf found from 200,000 to 6,000,000 per cubic centimeter in the milk in Munich.

Buiwid examined the milk in Warsaw, where there was an average of 4,000,000 per cubic centimeter. In the milk immediately after it was drawn from the cow he found from 10,000 to 20,000 per cubic centimeter.

In Amsterdam, Geuns found 2,500,000 per cubic centimeter in the fresh milk, but at the end of ten hours the number had increased to 10,500,000 per cubic centimeter.

Renk examined the market milk of Halle and found from 6,000,000 to 30,700,000 per cubic centimeter.

In May, 1892, Uhl studied the milk in Giessen; his thirty tests gave results from 83,000 to 169,600,000 per cubic centimeter. In the following June he found 10,500 to 13,600,000 per cubic centimeter. The average in May was 22,900,000 per cubic centimeter, but in June it was only 2,900,000. Uhl explains this difference by the supposition that the cows and stables were kept clean during this latter month, and by the additional supposition that there may have been less night's milk milked with the morning's milk.

A very systematic examination was made of more than 100 samples of the milk in Dorpat by Dr. Hugo Knochenstiern, mostly in September and October, 1892. He divided the samples into four classes according to their sources. The averages of the numbers in the several classes ranged from ten to thirty millions per centimeter.

## AMERICAN INVESTIGATIONS.

But little has been done in this direction in the United States. In 1892 Sedgwick and Batchelder examined a number of specimens of milk from Boston. They found, as an average of several tests, that the milk obtained in a clean stable from a well-kept cow, by milking into a sterilized bottle, contained 530 bacteria per cubic centimeter. But when the milking was done under the ordinary conditions of farm practice, the number of bacteria

* There are 946 cubic centimeters in a quart.

reached, on the average, 30,500. From fifteen samples of milk obtained from the homes of people in the suburbs of Boston, the average was 69,000 germs; from fifty-seven samples from milkmen the average was 2,355,000; and from sixteen samples secured at groceries the average was 4,577,000 germs per cubic centimeter.

### THE INVESTIGATION HERE REPORTED.

The milk used for the investigations, of which the details are given beyond, was obtained as delivered by milkmen to customers in Middletown. It was placed in a sterilized* flask and taken directly to the laboratory, where it was immediately "plated."

### METHOD OF CONDUCTING THE EXPERIMENTS.

All of the apparatus was sterilized in dry heat at a temperature of 160° C. (310° F.) Distilled water, which had been sterilized by boiling on three successive days, was used for diluting.

One cubic centimeter of the milk or cream to be tested was taken in a sterilized pipette and introduced into a flask containing ninety-nine cubic centimeters of the sterilized distilled water. After this had been thoroughly shaken to insure the even distribution of the germs, another sterilized pipette was used to draw out one cubic centimeter of the diluted milk. This was inoculated into a test tube containing about one inch of gelatine culture material, which had been liquefied by placing the tube in warm water. The gelatine and diluted milk were thoroughly mixed together and then poured out on a glass plate, which rested on the surface of cold water. Before hardening, the gelatine was spread by the aid of sterilized platinum wire, into a rectangular form. The plates, after hardening, were placed in covered glass dishes and left at room temperature until the colonies of bacteria were grown. The time varied from thirty-six hours to seven or eight days. In estimating the number of bacteria, from ten to twenty fields were counted in different parts of the plate. Multiplying the average number of colonies in a square centimeter by the number of square centimeters, gave the number of colonies on a plate. This, multiplied by one hundred gave the number of colonies in a cubic centimeter of the original milk, and since each colony had grown from one bacterium, it gave the number of bacteria originally present in a cubic centimeter of the milk.

* That is, a flask which had been heated to such a temperature as to kill all bacteria present in it.

TABLE 13.

*Number of Bacteria in Sweet Milk, Curdling Milk and Ripening Cream.*

| No. | Date. | Dilution. | Age in Days. | Number of Bacteria in One Cubic Centimeter.* I. | II. | III. | IV. | Average. |
|---|---|---|---|---|---|---|---|---|
| | *Sweet Milk.* *1894.* | | | | | | | |
| 1 | February 19, | 1:50 | *Less than one day. Generally 3 to 6 hours old.* | 37,550 | 36,000 | 28,050 | — | 34,000 |
| 2 | February 19, | 1:100 | | 44,700 | 36,900 | 36,600 | — | 39,000 |
| 3 | March 15, | 1:100 | | 169,000 | 128,800 | 182,700 | — | 160,000 |
| 4 | April 2, | 1:100 | | 45,000 | 38,000 | 49,400 | 42,300 | 44,000 |
| 5 | April 3, | 1:100 | | 11,600 | 9,800 | 12,200 | — | 11,000 |
| 6 | April 7, | 1:100 | | 25,800 | 18,500 | 22,400 | 19,200 | 21,000 |
| 7 | April 7, | 1:100 | | 3,888,000 | 3,283,200 | 3,931,200 | 2,592,000 | 3,424,000 |
| 8 | June 7, | 1:200 | | 514,800 | 398,800 | 140,400 | 405,000 | 386,000 |
| 9 | June 8, | 1:1000 | | 6,364,000 | 8,415,000 | 11,232,000 | 7,797,000 | 8,452,000 |
| 10 | June 16, | 1:100 | | 94,000 | 125,000 | 78,000 | — | 99,000 |
| 11 | June 16, | 1:100 | | 69,000 | 51,000 | 102,000 | — | 74,000 |
| 12 | June 16, | 1:100 | | 104,500 | 101,000 | 110,400 | 108,800 | 106,000 |
| 13 | June 16, | 1:100 | | 22,400 | 26,300 | — | — | 24,000 |
| | *Curdling Milk.* | | | | | | | |
| 14 | February 22, | 1:5000 | 3 | 89,280,000 | 84,150,000 | — | — | 86,715,000 |
| 15 | February 26, | 1:10000 | 7 | 227,700,000 | 171,000,000 | 198,720,000 | 223,280,000 | 207,675,000 |
| 16 | March 5, | 1:10000 | 7 | 224,460,000 | 265,500,000 | 371,250,000 | 207,900,000 | 267,302,500 |
| 17 | March 10, | 1:10000 | 2½ | 388,800,000 | 387,450,000 | 526,650,000 | 646,380,000 | 487,320,000 |
| 18 | April 10, | 1:10000 | 5 | 820,800,000 | 1,184,130,000 | 936,000,000 | — | 980,310,000 |
| 19 | April 11, | 1:10000 | 4 | 752,940,000 | 1,036,800,000 | 682,650,000 | — | 824,130,000 |
| 20 | April 12, | 1:10000 | 10 | 813,150,000 | 835,200,000 | 776,790,000 | 753,480,000 | 794,655,000 |
| 21 | April 12, | 1:10000 | 5 | 570,240,000 | 640,800,000 | 384,480,000 | 742,500,000 | 587,005,000 |
| 22 | June 10, | 1:10000 | 2 | 344,520,000 | 416,160,000 | 405,000,000 | 408,870,000 | 393,520,000 |
| 23 | June 10, | 1:10000 | 3 | 48,240,000 | 66,600,000 | 60,750,000 | — | 58,530,000 |
| | *Ripening Cream.* | | | | | | | |
| 24 | April 5, | 1:10000 | Just as collected | 4,000,000 | 5,700,000 | 6,000,000 | 540,000 | 4,060,000 |
| 25 | April 7, | 1:10000 | Aft. rp'ng 48 hrs | 473,480,000 | 503,880,000 | 257,040,000 | 149,760,000 | 346,040,000 |

* There are 946 cubic centimeters in one quart.

In table 13 it will be noticed that No. 7 and No. 9 are from the same source and give much larger numbers than the other tests. The milk in those two tests was from ten to twelve hours older than in the other samples, being night's milk while all the others were morning's milk. No. 10 is from the same source, but in that case a special request was made at the milk cart for morning's milk for examination. The result shows the difference between the morning's and the previous night's milk.

The average in the thirteen tests made is a little less than one million per cubic centimeter (990,000). But if the average is taken without including No. 7 and No. 9, which were probably night's milk, the average is reduced to less than 100,000 germs per cubic centimeter.

## BACTERIA IN BUTTER.

Probably the first attempt at a quantitative estimate of bacteria in butter was made by Von Lafar at the Hygienic Institute of the University of Munich in the winter of 1890–91. He found that butter fresh from the churn contained an immense number of germs and that this number quickly fell to one or two millions or less per gram.*

In the work here reported the changes in number of bacteria in butter kept under usual household conditions have been studied. The methods employed were practically the same as those already described for milk. The butter was weighed instead of being measured and the number of bacteria were calculated per gram* instead of per cubic centimeter. Two lots of unsalted and two of salted butter obtained from the creamery as soon as made, were tested. In each instance the butter was received in pound prints and the first plates were made as soon as received. The butter was kept in an ordinary refrigerator (at 32° to 38° F.) and plates were made every few days.

The first few tests were taken from different portions of the outside of the butter roll, as the difference between the number of germs living on the outside of the butter and those living on the inside were probably slight while the butter was fresh. Later, when the difference might be appreciable, the roll was cut at various places and samples taken from as near the center as possible for the inside determination, in order to compare it with the outside.

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* One pound weighs 454 grams.

TABLE 14.

*Number of Bacteria in Unsalted Butter.*

| No. | Date. | Dilution. | Weight. | Number Per Plate. I. | II. | III, | IV. | Average Per Plate. | ** Average Per Gram. |
|---|---|---|---|---|---|---|---|---|---|
| | *Lot A.* | | | | | | | | |
| 1, | May 1, | 1:2000 | .2941 | 36,288,000 | 34,194,000 | 33,660,000 | 31,500,000 | 33,910,500 | 115,302,000 |
| 2, | May 2, | 1:2000 | .1955 | 8,190,000 | 7,722,000 | — | — | 7,956,000 | 40,696,000 |
| 3, | May 4, | 1:2000 | .2615 | 4,080,000 | 3,432,000 | 1,980,000 | 1,620,000 | 2,778,000 | 10,623,000 |
| 4, | May 10, | 1:2000 | .778 | 8,648,000 | 7,102,000 | 8,640,000 | 9,828,000 | 8,554,500 | 10,995,000 |
| 5, | May 15, | 1:2000 | .3928 | 10,080,000 | 7,938,000 | 18,144,000 | 15,750,000 | 12,978,000 | 33,500,000 |
| 6, | May 21, | 1:2000 | .5160 | 11,520,000 | 24,300,000 | 16,872,000 | — | 17,564,000 | 34,039,000 |
| 7, | May 25, | 1:2000 | .4365 | 59,292,000 | 76,032,000 | 66,690,000 | 67,968,000 | 67,493,000 | 154,623,000 |
| 8, | May 30, | 1:2000 | .219 | 11,160,000 | 13,980,000 | 10,350,000 | 11,196,000 | 11,671,500 | 53,294,000 |
| 9,* | May 30, | 1:2000 | .462 | 256,000 | 314,000 | 306,000 | 276,000 | 285,000 | 618,000 |
| | *Lot B.* | | | | | | | | |
| 10, | May 26,† | — | — | — | — | — | — | — | — |
| 11, | May 27,† | — | — | — | — | — | — | — | — |
| 12, | May 29, | 1:2000 | .3048 | 9,072,000 | 14,742,000 | 17,820,000 | 14,162,000 | 13,936,000 | 45,726,000 |
| 13, | June 5, | 1:2000 | .5786 | 13,860,000 | 15,768,000 | 20,160,000 | 20,250,000 | 17,509,500 | 30,262,000 |
| 14,* | June 5, | 1:2000 | .7689 | 12,551,000 | 13,440,000 | 16,560,000 | 18,225,000 | 15,194,000 | 19,760,000 |
| 15, | June 11, | 1:2000 | .5100 | 5,100,000 | 4,418,000 | 6,624,000 | — | 5,380,000 | 10,551,000 |
| 16,* | June 11, | 1:2000 | .5745 | 4,620,000 | 4,130,000 | 5,762,000 | 4,480,000 | 4,748,000 | 8,265,000 |
| 17, | June 16, | 1:2000 | .3432 | 2,052,000 | 1,116,000 | 1,944,000 | — | 1,704,000 | 4,965,000 |
| 18,* | June 16, | 1:2000 | .3755 | 1,730,000 | — | — | — | 1,730,000 | 4,605,000 |
| 19, | June 20, | 1:2000 | .1960 | 1,581,000 | 525,000 | 540,000 | 567,000 | 801,000 | 4,098,000 |
| 20,* | June 20, | 1:2000 | .2877 | 1,354,600 | 1,872,000 | 883,000 | 1,180,000 | 1,322,000 | 4,595,600 |
| 21, | June 21,* | 1:2000 | .348 | 17,748,000 | 24,426,000 | 29,952,000 | — | 24,042,000 | 69,086,000 |
| 22, | June 22,† | 1:2000 | .18 | 11,664,000 | 8,514,000 | 8,424,000 | — | 9,534,000 | 52,967,000 |

* All those marked * were taken from the interior of the butter ball; the others were all from the outer portion.

† June 21 and 22 substituted for May 26 and 27, which were lost by contamination of water.

** There are 454 grams in one pound.

## Table 15.

*Number of Bacteria in Salted Butter.*

| No. | Date. | Dilution. | Weight. | Number Per Plate. I. | II. | III. | IV. | Average Per Plate. | ** Average Per Gram. |
|---|---|---|---|---|---|---|---|---|---|
| | *Lot A.* | | | | | | | | |
| 1, | May 1, | 1:2000 | .7230 | 39,168,000 | 41,850,000 | 38,880,000 | 36,760,000 | 39,167,000 | 54,173,000 |
| 2, | May 2, | 1:4000 | .3605 | 11,016,000 | 7,344,000 | 11,368,000 | 8,044,000 | 9,443,000 | 26,194,000 |
| 3, | May 4, | 1:2000 | .6250 | 6,156,000 | 6,534,000 | 6,624,000 | 4,950,000 | 6,066,000 | 9,706,000 |
| 4, | May 10, | 1:2000 | .3612 | 426,000 | 456,000 | 866,000 | 1,350,000 | 774,500 | 2,144,000 |
| 5, | May 15, | 1:2000 | .4730 | 946,000 | 1,620,000 | 1,440,000 | — | 1,335,333 | 2,821,000 |
| 6, | May 21, | 1:2000 | .3900 | 480,000 | 528,000 | 320,000 | 368,000 | 424,000 | 1,087,000 |
| 7, | May 25, | 1:1000 | .3098 | 81,000 | 207,000 | 144,000 | 63,000 | 123,750 | 300,000 |
| 8,* | May 25, | 1:1000 | .8079 | 1,728,000 | 1,080,000 | 1,035,000 | 990,000 | 1,208,250 | 1,495,000 |
| 9, | May 30, | 1:1000 | .2765 | 80,000 | 57,000 | 113,000 | 90,000 | 85,000 | 307,000 |
| 10,* | May 30, | 1:1000 | .4100 | 339,000 | 368,000 | 333,000 | 282,000 | 330,500 | 806,000 |
| | *Lot B.* | | | | | | | | |
| 11, | May 26,† | — | — | — | — | — | — | — | — |
| 12, | May 27,† | — | — | — | — | — | — | — | — |
| 13, | May 29, | 1:2000 | .4038 | 6,000,000 | 9,280,000 | 9,072,000 | 8,190,000 | 8,135,500 | 20,147,000 |
| 14, | June 5, | 1:1000 | .3810 | 1,800,000 | 1,932,000 | 1,200,000 | 1,932,000 | 1,721,000 | 4,517,000 |
| 15,* | June 5, | 1:2000 | .4334 | 3,504,000 | 7,480,000 | 5,928,000 | 5,700,000 | 5,653,000 | 13,043,000 |
| 16, | June 11, | 1:2000 | .4942 | 1,198,000 | 2,580,000 | 1,772,000 | 1,702,000 | 1,813,000 | 3,668,000 |
| 17,* | June 11, | 1:2000 | .7468 | 2,912,000 | 1,560,000 | 2,700,000 | — | 2,390,000 | 3,201,000 |
| 18, | June 16, | 1:1000 | .3877 | 700,000 | 203,000 | 270,000 | — | 391,000 | 1,009,000 |
| 19,* | June 16, | 1:1000 | .4540 | 402,000 | 409,000 | 363,000 | — | 391,333 | 862,000 |
| 20, | June 20, | 1:1000 | .4356 | 451,000 | 1,350,000 | 450,000 | 360,000 | 652,250 | 1,497,000 |
| 21,* | June 20, | 1:1000 | .3376 | 510,000 | 460,000 | 350,000 | 406,000 | 431,500 | 1,277,000 |
| 22, | June 21,† | 1:2000 | .2962 | 12,960,000 | 13,320,000 | 9,360,000 | 10,800,000 | 11,610,000 | 39,196,000 |
| 23, | June 22, | 1:2000 | .2750 | 5,100,000 | 9,660,000 | 9,000,000 | 6,240,000 | 7,500,000 | 27,272,700 |
| | *Salted Butter One Year Old.* | | | | | | | | |
| 24, | June 1, | 1:2000 | .3720 | 20,000 | 44,000 | 48,000 | 50,000 | 40,500 | 109,000 |
| 25, | June 1, | 1:2000 | .2681 | 54,000 | 22,000 | 44,000 | — | 40,000 | 149,000 |

* Those marked * were taken from the interior of the butter ball; the others were all from the outer portion.

† June 21 and 22 substituted for May 26 and 27, which were lost by contamination of water.

** There are 454 grams in one pound.

Tables 14 and 15, which precede, give the results of the studies made upon butter.

It will be observed that there is a constant decrease in the number of bacteria as the butter becomes older. In general this decrease is most marked at the very outset. In the case of the first lot of unsalted butter 65 per cent. of all the bacteria present died off in the first day. Ripened cream contains immense numbers of germs, hence it would be expected that freshly churned butter would also contain large numbers. After a number of days the number of bacteria are in general smaller in the inner than in the outer portions of the butter.

## SUMMARY.

*The number of bacteria in milk increases very rapidly with the age of the milk. This increase is most rapid when milk is kept warm, as warmth is favorable to the growth of the organisms. Cooling milk as rapidly as possible and keeping at a low temperature hinders the development of the germs.*

*The number of bacteria in milk as ordinarily sold may vary from thousands to millions per cubic centimeter. The smallest number found in milk sold in Middletown was eleven thousand per cubic centimeter and the largest number was nearly eight and a half millions. As there are 946 cubic centimeters in a quart, these figures mean that the milk had from ten million to eight billion (eight thousand million) bacteria per quart.*

*The presence of only a small number of bacteria in milk indicates care and cleanliness in its handling and storage and also that it is comparatively freshly drawn. Sour milk and ripened cream contain many millions of bacteria in a cubic centimeter.*

*The number of bacteria in butter, whether salted or unsalted, gradually diminishes as the age of the butter increases. In butter a year old the number becomes very small indeed. There is a more rapid decrease of bacteria in butter during the first few hours than is exhibited later and there is a more rapid decrease in the inside of the butter roll than on the outside. The decrease in salted butter is much greater in the first few hours than that of unsalted butter.*

# BACTERIA IN THE DAIRY.

BY H. W. CONNN.

## VIII. CREAM RIPENING WITH PURE CULTURES OF BACTERIA.

In the Annual Report of this Station for 1893, pp. 43–68, there were given a series of experiments upon cream ripening with a considerable number of species of bacteria which had been isolated from normal milk and cream. These experiments have been continued, with an interruption during the summer months, until the present time, and the details of the further experiments are given in the present article.

The majority of the species of bacteria which are described below, and which have been used in all of the experiments upon which the present paper is based, have been obtained from milk products. Some of them have been isolated from ripening cream from several different places in Connecticut; some of them have been isolated from sour or sweet milk; and some from fermented milk; several of them were obtained from a lot of milk which had been sent to the Columbian Exposition from Uruguay as an illustration of certain food products. A few were obtained from the air and several from water. In all cases, with the exception, therefore, of the water bacteria, the species in question may be regarded as normal milk bacteria, and their effect upon cream in its ripening and upon the butter subsequently obtained by churning the cream is, therefore, of considerable practical importance in enabling us to understand normal dairy products. The description of the species will therefore be given in more or less detail.

### DESCRIPTION OF SPECIES.

No. 34.

*Locality*—Isolated from the air in Jackson Park at Chicago, in August, 1893.

*Morphology.*—A spherical organism which has the characteristics of the genus Merismopœdia. Size .4 $\mu$.

*Motility.*—No motion.

*Relation to Air.*—Grows well under mica plate.

*Temperature.*—Grows profusely at 35° C., though not producing color. Grows also at 20°.

*Colony on Gelatine.*—A liquefying pit is formed with a nucleus and a cloudy edge. Differs from most liquefying colonies in not being clear round the rim, but uniformly cloudy to its extreme edge.

*Gelatine Stab Culture.*—Growth is abundant along the needle track. There is a slight surface growth which does not spread, is rather thick and does not very thoroughly liquefy the gelatine.

*Agar-Agar.*—A thick, moist layer with a sharp edge tinged with yellow.

*Potato.*—No visible growth.

*Milk.*—Is not affected either at 20° or at 35°.

*Bouillon.*—Becomes slightly cloudy with a tough, yellowish sediment. After four weeks liquid becomes clear.

No. 38.

This is the well-known *Bacillus subtilis.*

No. 40.

*Locality.*—Found in a lot of milk from Uruguay, South America, at Chicago.

*Morphology.*—A large micrococcus, size, .9 $\mu$.

*Motility.*—Non-motile.

*Relation to Air.*—Will grow under mica plate.

*Colony on Gelatine.*—Forms a little pit with a center granular yellowish nucleus and an outer lobate granular ring. Sometimes the pit contains a yellowish granular mass without a rim. Sometimes there is formed an irregular lobate liquefying pit.

*Gelatine Stab Culture.*—Slow growth. Forms a narrow funnel or sometimes a deep pit which is quite dry. There is formed a thick liquid with a yellowish sediment and a yellowish scum. The gelatine never completely liquefies even after weeks of growth.

*Agar-Agar.*—Forms a Naples yellow, rough, dry layer with a sharp edge.

*Potato.*—Forms a Naples yellow, dry, mounded, thick layer, the color not so brilliant as on agar.

*Milk.*—After five days at 35° the milk is curdled into a soft curd with no whey. The reaction is acid. After a month it becomes much harder with yellowish flakes and there is no digestion of the curd.

*Bouillon.*—Remains clear with a slight, flaky scum and a slight sediment. After four weeks' growth the whole liquid clears up retaining simply a slight yellowish sediment.

No. 40 is closely allied to No. 2 described in the last Annual Report. It differs only in its ability to grow under mica and slightly in its growth in gelatine.

No. 41.

See page 57 of this Report.

No. 43.

*Locality*—From specimen of Uruguay milk.

*Morphology.*—An oval micrococcus or a short rod not forming chains nor spores. Size, .9 $\mu$ by .7 $\mu$.

*Motility.*—Non-motile.

*Relation to Air.*—Will grow under mica plate.

*Colony on Gelatine.*—A smooth, round, slightly raised white bead.

*Gelatine Stab Culture.*—A beaded needle track with an abundant growth. A raised, transparent surface layer which thickens into a quite thick white mass.

*Agar-Agar.*—A very thin, transparent, extremely tenacious yellow layer which adheres to the needle and is not easily spread or diffused through water.

*Potato.*—No visible growth.

*Milk.*—No noticeable effect upon milk. After several weeks there is a slight acid reaction in the milk, but not sufficient to curdle the milk when heated.

*Bouillon.*—Liquid becomes uniformly cloudy with a dense, tough, yellowish sediment. After four weeks the liquid clears retaining the sediment.

No. 44.

*Locality.*—Milk from Uruguay.

*Morphology.*—A large micrococcus 1.5 $\mu$ in diameter.

*Motility.*—Non-motile.

*Relation to Air.*—Will grow under mica plate.

*Temperature.*—Grows well at 35° and at 20°.

*Colony on Gelatine.*—A smooth, round, raised gray colony. Sometimes there is formed a whitish bead at first which spreads into a grayish colony of small size.

*Gelatine Stab Culture.*—There is an abundant needle growth with a thin, transparent, slightly spreading surface growth. Sometimes in old cultures the surface is sunken into a dry pit.

*Agar-Agar.*—A thin, whitish, dry iridescent growth, rather tough and not dissolving in water.

*Potato.*—A yellowish or slightly brown growth turning the potato dark colored.

*Milk.*—No change in the milk although after a couple of months' growth the milk becomes rather thick and transparent. Reaction is hardly affected.

*Bouillon.*—A uniformly cloudy liquid, especially cloudy at the surface, where there is a thick cloudy layer of considerable depth, but no true scum. After four weeks the liquid is still cloudy with a slight scum.

No. 45.

*Locality.*—From Chicago. Isolated from a lot of fermented milk (Matzoon). The milk had a pure, clean, sour taste and a fine curd.

*Morphology.*—A species of Sarcinnia, .7 $\mu$ in diameter.

*Motility.*—Non-motile.

*Relation to Air.*—Grows under mica plate.

*Temperature.*—Grows abundantly at 35°, producing abundant culture. Grows well at 20°.

*Colony on Gelatine.*—A large, slightly sunken colony, with a nucleus and granular edge.

*Gelatine Stab Culture.*—Slight growth along needle track, forming a yellowish dry layer on the surface of the gelatine.

*Agar-Agar.*—A bright, yellow raised layer with sharp edges and not very diffusely spreading.

*Potato.*—Very slight growth on potato, with a slight yellowish tinge.

*Milk.*—No effect on milk at any temperature.

*Bouillon.*—The liquid remains clear, but a sediment appears and also flakes arise on the sides of the tubes. These flakes continue to make their appearance and sink to the bottom for some time. After four weeks the liquid is clear, with a distinct sediment.

No. 46.

*Locality.*—From Matzoon, at Jackson Park, Chicago.

*Morphology.*—A short rod which forms chains of two or sometimes more. Size, .8 by .4 $\mu$ on agar; slightly smaller on potato.

*Motility.*—Possesses motion.

*Relation to Air.*—Will grow under mica plate.

*Temperature.*—Grows well at 35°, producing its color. Grows also at 20°.

*Colony on Gelatine.*—A pit is formed with a rough crenate mass at the center. It spreads rapidly, becoming granular, and finally forms a pit with a nucleus and a clear rim.

*Gelatine Stab Culture.*—An abundant needle growth is formed at first, and then a shallow pit at the surface, which slowly deepens, and after about eleven days forms a layer of liquefied gelatine half an inch deep.

*Agar-Agar.*—A very thin, white, smooth layer which subsequently becomes yellowish.

*Potato.*—A thick growth which is of a bright lemon yellow color.

*Milk.*—The milk is very slowly affected. After about three weeks it is curdled into a soft mass which is either weakly alkaline or amphoteric in reaction. After six weeks' growth it becomes slightly brown, and if kept at 35°, eventually is almost completely digested into a transparent brownish liquid which finally becomes almost mahogany colored. If the organism is cultivated at 35° for nine days and is then heated to a boiling temperature, the milk curdles.

*Bouillon.*—Liquid becomes very cloudy, with a yellow precipitate forming. After four weeks it still remains cloudy with a dense precipitate.

No. 47.

*Locality.*—From the air at Middletown.

*Morphology.*—A small micrococcus .4 $\mu$ in diameter.

*Motility.*—None.

*Relation to Air.*—Does not grow under mica plate.

*Temperature.*—Grows profusely at 35°.

*Colony on Gelatine.*—A small, round, smooth, raised, snow-white bead.

*Gelatine Stab Culture.*—An abundant growth along needle track with a thick, moist, but not widely spread surface growth.

*Agar-Agar.*—A very moist, almost watery snow-white growth not very widely spreading.

*Potato.*—Very watery, spreading over the surface of the potato. Snow white.

*Milk.*—No effect upon the milk except a slight increase in alkalinity after about three weeks. At 35° there is sometimes a slight increase in thickness of the liquid.

*Bouillon.*—A uniformly cloudy liquid rather clear at the surface. After four weeks the whole liquid clears up with a sediment.

No. 48.

Organism No. 48 is almost identical with *Bacillus erythrogenes.* It differs from the latter only in producing no growth on potato and in producing a brownish red rather than a blood-red milk.

No. 49.

*Locality.*—Air from Middletown.

*Morphology.*—A large micrococcus 1 $\mu$. in diameter.

*Motility.*—None.

*Relation to Air.*—Does not grow under mica plate.

*Temperature.*—Grows very slowly at 35°. Color not well developed at this temperature.

*Colony on Gelatine.*—Not characteristic.

*Gelatine Stab Culture.*—Slight needle growth and a slight superficial growth which is orange colored.

*Agar-Agar.*—A very thick dark orange growth which is quite transparent.

*Potato.*—No visible growth.

*Milk.*—No effect on milk at any temperature.

*Bouillon.*—A uniformly slightly cloudy liquid, which clears up after four weeks with a sediment.

No. 51.

*Locality.*—Ripened cream from Durham, Conn.*

*Morphology.*—A large rod in long chains. Rods with square ends, forming large spores in the middle. Size, 1.5 to .2 by .8 $\mu$. When growing on agar the chains break up into short rods.

*Motility.*—None.

*Relation to Air.*—Will grow under mica plate, but not much except near the edge.

*Temperature.*—Grows rapidly at 35°, less rapidly at 20°.

*Colony on Gelatine.*—A slight liquefying colony forming peculiar characteristic contorted masses with the threads arranged in parallel rows. Colony very much like that of Proteus. Very characteristic.

*Gelatine Stab Culture.*—Growth is slow. A shallow pit is formed which, after two or three weeks, liquefies about half an inch of gelatine. The pit is always cone shaped and liquefaction never proceeds very far even in the oldest cultures.

*Agar-Agar.*—An abundant, spreading growth, quite dry and granular, and having somewhat the appearance of ground glass.

*Potato.*—A dry, velvety white, sometimes even snow-white growth, becoming very thick.

*Milk.*—Curdles in two days into a soft, jelly-like mass which is weakly alkaline and is rapidly digested into a cloudy, yellowish liquid with an abundant sediment. The final digested mass is distinctly alkaline.

*Bouillon.*—A clear liquid with a scum forming at the surface which sinks in flaky masses when disturbed.

No. 52.

*Locality.*—Cream from Cromwell.

*Morphology.*—A minute micrococcus .3 $\mu$ in diameter forming chains which have a tendency to arrange themselves into rings.

*Motility.*—Non-motile.

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* A variety of the same species has been found in snow in Middletown, Conn.

*Relation to Air.*—Will grow under mica plate.

*Temperature.*—Grows rapidly at both 20° and 35°.

*Colony on Gelatine.*—A smooth, round, raised white colony which reaches the diameter of 1 mm. Colony very white and not spreading.

*Gelatine Stab Culture.*—A typical nail culture with an abundant needle growth and a snow-white, thick, raised, round surface growth.

*Agar-Agar.*—An abundant, thick, smooth, glistening white growth.

*Potato.*—Very abundant growth spreading over the potato, quite thick and snow white.

*Milk.*—Curdles at 35° in three days; at 20° in six days. Curd is soft and acid and has the odor of ordinary sour milk.

*Bouillon.*—Uniformly cloudy growth with a slight sediment.

No. 53.

*Locality.*—Milk from Middletown.

*Morphology.*—A short bacillus.

*Motility.*—None.

*Relation to Air.*—Grows slightly under mica.

*Temperature.*—Grows well at 20° or at 35°.

*Colony on Gelatine.*—A large raised bead which spreads over the surface as a white, smooth colony 1 mm. in diameter.

*Gelatine Stab Culture.*—Abundant needle growth, somewhat granular. Surface growth is abundant, somewhat spreading, pearly white and waxy. Abundant gas bubbles produced in the gelatine.

*Agar-Agar.*—An abundant, thick, raised white growth, not specially characteristic.

*Potato.*—A white growth tinged with brownish, quite abundant, usually thick, though sometimes thin and spreading where potato is very moist.

*Milk.*—Curdles in two to three days at a temperature of 20°. Is very acid. Curd is hard with a little whey, and does not digest.

*Bouillon.*—Slightly cloudy bouillon with a slightly thick precipitate.

No. 54.

*Locality.*—Milk from Middletown.

*Morphology.*—

*Motility.*—None.

*Relation to Air.*—Will grow under mica plate.

*Temperature.*—Grows at 37° and also at the temperature of the room.

*Colony on Gelatine.*—A large surface colony, irregular or lobate in outline, white.

*Gelatine Stab Culture.*—Slight needle growth or a thin, irregular surface growth.

*Agar-Agar.*—White layer not especially characteristic.

*Potato.*—

*Milk.*—Does not curdle at temperature of the room in seven days, but the milk becomes distinctly acid. Becomes slightly thick with a clear stratum on top.

*Bouillon*—Cloudy bouillon with white precipitate.

This organism was lost before its characters were completely determined.

No. 55.

*Locality.*—Milk from Middletown.

*Morphology.*—A short rod with rounded ends. Size, 1 by .8 μ. Contains clear bodies which look like spores.

*Relation to Air.*—Grows under mica.

*Motility.*—Non-motile.

*Temperature.*—Slight growth at 35°.

*Colony on Gelatine.*—Colonies below surface round and small. Surface colonies spread into good-sized white, slightly granular colonies. They are white with smooth contours.

*Gelatine Stab Culture.*—Slight growth along needle track. Surface growth is thin, semi-transparent and spreading.

*Agar-Agar.*—White growth which is not characteristic.

*Potato.*—Thick, spreading, irregular contoured growth which is slightly lemon color.

*Milk.*—No effect except a slight transparency.

*Bouillon.*—A clear liquid shows a flaky precipitate.

No. 56.

*Locality.*—Milk from Middletown.

*Morphology.*—Bacilli with rounded ends. In pairs but no chains. Size, 1.2 μ by .8 μ.

*Motility.*—Non-motile.

*Relation to Air.*—Grows under mica plate.

*Temperature.*—Grows at 20° also rapidly at 35°, with wrinkled surface.

*Colony on Gelatine.*—Surface colonies large, white, thin and transparent. They are irregular and lobate in outline and with irregular surface.

*Gelatine Stab Culture.*—Surface growth is clear, irregular edged and thin. An abundant granular needle track growth.

*Agar-Agar.*—Thin, white, spreading. If the agar is dry the growth does not spread but shows parallel rows of colonies on each side of inoculation line.

*Milk.*—Milk becomes very acid but does not curdle.

*Bouillon.*—Slightly cloudy with white sediment.

With the organisms above described experiments upon cream ripening have been carried on for the last eight months. In all there have been about 200 of these experiments up to the present time. The experiments have been identical with those described in the Annual Report* of a year ago, and each experiment was conducted as follows: A small lot of milk was passed through a separator, and the cream obtained therefrom was divided into two lots and placed in two sterilized cans. Both lots were then pasteurized in hot water at a temperature of 69° C. (156° F.) Into the pasteurized cream was poured about 25 cubic centimeters of a milk culture of one of the organisms to be experimented on. The two lots were always inoculated differently in order that a

* Sixth Annual Report of this Station, 1893, pp. 43–60.

careful comparison may be made. Sometimes one was inoculated with one species and the other with another. Sometimes one was left without inoculation for control. The inoculated cream was then allowed to ripen at varying temperatures and for varying lengths of time. The temperatures which have been adopted have been 20° C. (68° F.) and 24° C. (75° F.), and the length of ripening has been usually 24 hours, though in some cases 48 hours. After the ripening a careful examination of the ripened cream was made, the cream was churned and the butter also carefully examined as to taste and flavor, both with and without salting. With each of the organisms above described several experiments have been performed, in most cases eight to ten, and in all cases enough to bring about uniform results. Where a half dozen experiments followed each other with absolutely uniformity the organism in question was no longer experimented with, but another was taken. But whenever any lack of uniformity arose in the results of the first half dozen experiments, the experiments with the organism were continued until absolute uniformity was reached. In this way the effect upon the butter of ripening the cream with each organism was determined accurately. In the following descriptions it is not thought necessary to give the details of each of these experiments. Most of the 200 are duplicates of each other, and the essential results can be given just as well by describing a few experiments as by describing them all. It will be, of course, understood that in the following descriptions we have results which have been confirmed in every case by a series of experiments, and in no cases are the results of experiments isolated ones. They may, therefore, be regarded as accurate so far as this method of experimenting with pasteurized rather than sterilized cream makes accuracy possible.

### *Species No. 34.*

At a temperature of 20° for 24 hours or 36 hours the cream is scarcely changed. It remains thin and limpid, although it acquires a very slight acid reaction and a slight sweet taste. The butter made from it is good, but mild. It shows no decided flavor and lacks the desirable aroma present in properly ripened butter. It is, indeed, very similar to butter made from unripened cream. No. 34 is, therefore, a neutral species whose presence in normally ripened cream will have no great influence.

*Species No. 38.*

As will be noticed from the above description, No. 38 is the common *Bacillus subtilis*, an organism which is well known and abundant in and around barns and dairies. It is, therefore, of especial interest to notice the effect of this organism upon the ripening of cream and the flavor of the butter. For that reason a larger number of experiments were performed with No. 38 than with most of the others, and the experiments were practically uniform in their results. The cream under its influence was thickened, the amount of the thickening depending upon the length of ripening and the temperature. At 20° C. (68° F.) for 24 hours the cream was only slightly thickened as a rule, while, if ripened for a few hours longer, or if inoculated with a larger culture, the cream became quite thick, but not properly curdled. The reaction of the cream remained practically unchanged, the cream being essentially amphoteric, like normal fresh milk. There was noticed scarcely any change in the odor of the ripened cream, and it had hardly any appreciable taste. The peculiar flavor of fresh cream, however, had disappeared, and no prominent flavor or odor appeared in its place. The cream usually churns with considerable difficulty, and the butter made therefrom is poor in quality. There is no decidedly disagreeable taste unless the cream is over-ripened, but the action of this species seems to take away the somewhat pleasant flavor of the sweet cream which would ordinarily produce a delicate flavor of sweet cream butter. Although sweet cream butter is usually regarded as rather a tasteless product, it does have a slight and to many agreeable flavor. *Bacillus subtilis* completely destroys this delicate flavor and leaves the butter almost absolutely tasteless. It makes butter which is much inferior to that of sweet cream butter, because it takes away from the butter even the slight taste which it would have had without the ripening. *Bacillus subtilis* is, therefore, a species that is distinctly objectionable in ripening cream, and if present in any considerable quantity will result in a deterioration of the flavor and the quality of the butter. When, however, it is present in small quantity it probably will have no especial influence, because it has no decided flavor of its own, and if other organisms are present with it to give a proper flavor, *Bacillus subtilis* will probably produce no objectionable results.

*Species No. 40.*

The cream becomes slightly thickened at the end of 24 hours. If the ripening is continued for 48 hours it becomes decidedly thickened, or if ripened at a higher temperature than 25° C. (77° F.) The reaction is neutral, or if the ripening is continued it becomes slightly acid. It possesses a very slight, indescribable odor with practically no taste, the taste of the ripened cream being almost the same as that of the fresh sweet cream. The cream churns readily and produces a butter which is usually of a good grain, though occasionally soft and fluffy when the ripening is carried too far. The flavor of the butter is good, although not first-class. The specially desired butter aroma seems to be wholly absent. This species may be regarded, then, as a neutral species having no noticeable effect upon the butter, either in producing a good or a bad flavor. If present in ripening cream its influence will be inappreciable.

*Species No. 41.*

This species is more fully described elsewhere in this Report* and need not be mentioned again here.

*Species No. 43.*

This species is a neutral one. Only a few tests were made with it, but in these hardly any effect upon the butter was noticed. The butter was mild and possessed hardly any flavor.

*Species No. 44.*

A moderate temperature, either 20° C. (68° F.) or 23° C. (73° F.) for 24 hours, produces no appreciable effect upon the cream. It neither thickens nor changes its reaction, nor its flavor nor taste. The butter made from it is extremely mild and almost like sweet cream butter. When the cream is ripened at a higher temperature, or for 48 hours, it becomes quite thick and smooth, acquires an acid reaction with a sour but pleasant taste and produces butter which is good but very mild, and with no very prominent taste. No. 44 is thus like No. 40, a purely neutral species whose effect upon the cream is very slight indeed, and its effect upon the butter is so slight as to be inappreciable It would have no influence upon butter, either for good or for bad, if present in the normally ripening cream.

* This Report, pp. 57, 58.

### *Species No. 45.*

This species produces slight changes in the cream. If ripened at 23° C. (73° F.) for 24 hours, or at 20° C. (68° F.) for a longer period, the cream becomes slightly thick with a slight acid reaction. There is no appreciable odor, but there is rather of a pleasant, though sweetish taste. The taste is not just like sweet cream, but is quite distinctly sweet. The butter made therefrom is tolerably good butter, with very little flavor to be noticed. The flavor is too mild for first-class butter, and yet the butter would always be regarded as of a good quality. When the ripening is allowed to continue for two days, or at a higher temperature, the flavor still remains good, but the butter is apt to be soft and of a poor grain. No. 45, therefore, is a species which may be of some advantage in the ripening of cream, but will not of itself produce a proper butter flavor.

### *Species No. 46.*

This species produces a thickening of the cream which may be considerable if the ripening is carried to a little more than the ordinary limits. The reaction is slightly acid. There is very little change in the taste and flavor of the cream, although a very slight sweetish taste is noticed and an odor a little different from that of fresh cream. The butter is very apt to be poor in grain and is practically tasteless. This species is, therefore, another neutral species which neither has any good nor specially injurious influence upon the cream. It is not a species which has any distinct relation to the phenomena of cream ripening.

### *Species No. 47.*

This species produces a slightly thickened cream with an alkaline reaction. There is a peculiar, though indescribable odor, with a sweet, pleasant taste. The butter is good, quite hard and fine-grained. It is rather mild, although of a good flavor. The ripening may be carried on at a temperature as high as 28° C. for 24 hours without injury, or at 20° C. (68° F.) for 48 hours and not be over-ripened. This species is, therefore, one which may be of value in butter-making, and seemingly is one of those that directly contributes toward producing a good flavor. By itself, however, the proper aroma is hardly developed, the butter being too mild even when ripened for a long time.

*Species No. 48.*

Cream is very slightly thickened. Indeed, in some cases there is hardly any appreciable change in the appearance of the cream after ripening, even at a temperature as high as 28° C. When, however, the ripening is continued for a longer time the cream becomes thickened. The reaction is alkaline or amphoteric, and, hardly changed from the normal reaction of the milk. There is a very slight, not especially pleasant odor developed and a peculiar, sweet taste. The butter made from the cream has in every experiment a peculiar taste as if the cream had been over-heated in pasteurization. It was thought at first that this was due to over-heating, but the absolute uniformity with which this flavor appeared led to the conclusion that it was really a taste produced in the cream by the action of the organism itself. The butter was not good and would have been everywhere regarded as very poor in quality. No. 48, therefore, is an unfavorable species for butter-making. Although producing a good grained butter, from a cream which churns quickly, there is a tendency to give to the butter an unpleasant flavor which makes the organism injurious for normal butter-making.

*Species No. 49.*

By this organism the cream is slightly thickened into a smoothish mass which is alkaline or amphoteric in reaction. There is only a very slight flavor, but a sweet, pleasant taste in the cream. The butter made therefrom is of an excellent quality. It is not so good as that produced by No. 41 and yet has a pleasant, agreeable flavor and a good grain. It may be regarded, therefore, as one of the species of organisms advantageous to butter-making.

*Species No. 51.*

Cream is rendered somewhat thick and smooth by the action of this species when used for 24 hours at 20° C. (68° F.) The reaction is hardly changed. A peculiar, indescribable odor is noticed and a sweet, very pleasant taste to the cream. The butter made therefrom is mild, tolerably good in taste, though never producing a typical aroma such as desired in first-class butter. It is a species whose presence in the cream is of no special importance either in producing good or poor butter.

*Species No. 52.*

When ripened at ordinary temperatures and for ordinary length of time the cream remains thin although it becomes filled with bubbles of gas indicating the probable formation of carbon dioxide. If the temperature is raised the gas is more abundant and the cream becomes thicker. The reaction is acid when the ripening takes place in a typical fashion. The odor is that of typical sour milk or sour cream and the taste the same. The butter made therefrom is good with a slight acid flavor. The aroma is not developed but the butter has the acid flavor which is desired as one of the factors of a high quality butter. This organism is, therefore, one of the better species of cream bacteria and undoubtedly aids in producing a proper cream ripening and butter flavor.

*Species No. 53.*

This organism makes the cream more or less thick according to the length of the ripening, and produces an abundant gas. When the cream that has been ripened with No. 53 is agitated the gas rises in a mass of bubbles to the surface and sometimes collects in a froth. The cream is curdled if the ripening continues long enough. It is decidedly acid and has the well-known typical odor of sour milk. The taste is also like that of sour milk. Butter made therefrom possesses a moderate acid flavor which may be decidedly too acid if the ripening continues too long. There is not produced, however, any proper butter aroma, and although the butter is tolerably good it is not first-class butter from lacking the especially desirable character of high quality product.

*Species No. 54.*

No. 54 has very little effect upon the appearance of the cream unless the ripening is continued for a long time. The cream remains thin, no gas is produced, but it is rendered decidedly acid and acquires a peculiar, penetrating, rather strong odor, somewhat resembling garlic. The butter made therefrom is never of very good quality, although in some cases when the ripening has not been carried too far the butter is tolerably good. It is, however, never possessed of a proper butter aroma and usually has an unpleasant taste. The species is an unfavorable one for butter-making.

*Species No. 55.*

No. 55 has no appreciable effect upon the appearance of the cream. The cream remains thin and develops no gas. The cream is rendered slightly alkaline and possesses a peculiar, vile odor, which is sometimes decidedly strong and unpleasant. The taste is also bad and the butter made therefrom, though not having so strong a taste as the cream, is never good. There is no butter aroma; there is no acid taste and what taste there is, is an unpleasant one. The species is an unfavorable one for the butter-maker.

*Species No. 56.*

This organism produces an acid cream which is sometimes thickened if the ripening continues for a proper time, but if continued only a day the cream is quite thin. No gas is developed, but there is a strong, penetrating, pungent, or sometimes musty odor, and an unpleasant taste. The butter made therefrom is always poor. It does not have a very strong odor, but is usually of rather a brackish or sickish taste and lacks any desirable butter aroma.

In addition to the organisms above described, six other species of bacteria have been isolated from water by Dr. K. C. Mead, and with these organisms experiments in cream-ripening have been made. Without going into the details of the descriptions of the organisms, the results of their action upon butter may be noted as follows:

No. 1 produced butter with practically no taste and poor grain. No. 5 produced butter with a strong odor and taste of decay, the butter giving a slight indication of putridity; the cream was extremely vile in taste and flavor. No. 6 produced butter that was quite good but mild, and with a flavor that was not typical; it produced hardly any effect upon the cream and very little effect upon the butter. No. 7 produced butter which is essentially tasteless when the cream is ripened normally, or if the cream is over-ripened the butter is decidedly sour. No. 7 produced butter with a tolerably good grain, but with very little taste. The taste, however, was not bad except when over-ripened. The cream was hardly changed in its appearance or its reaction, and has very little odor or flavor. This species produced no good or ill effect upon the butter. No. 8 has a slight thickening effect upon the cream and gives rise to a good grained but absolutely tasteless

butter. It is worse than No. 7, the flavor being inferior to that made from sweet cream.

These experiments are still in progress, and it appears best to defer a summary and discussion of them until a later period when other experiments can be published in detail. It may perhaps be well, however, to notice the relation of the species experimented with up to this time to the power of producing lactic acid. The phenomena which is in this vicinity called "ripening" is frequently called "souring," and is practically always accompanied in normal butter-making by the production of lactic acid. It will be seen, however, from the various experiments already published, that the souring of the cream is only one of the phenomena, and that the production of a proper butter flavor is dependent upon some changes entirely independent of the formation of lactic acid. The fact that in some cases the bacteria do not produce the same reaction in the cream as in sterilized milk is doubtless due to the uncertainties of pasteurization. Of the 29 species of bacteria whose effect upon butter has been described in this paper and in the previous report, 10 produce acid in milk and cream, and therefore sour the cream, viz.: Nos. 5, 16, 16*i*, 18, 20, 21, 40, 52, 54, and 56. Of these only two make what has been regarded as *good* butter, viz.: Nos. 16 and 52. Five have been found to make milk and cream slightly acid without souring it to any noticeable degree, viz.: Nos. 34, 41, 44, 45, 46. Of these two, Nos. 41 and 45 produce *good* butter. Twelve either have no effect on the butter or render it slightly alkaline, viz.: Nos. 2, 22, 27, 19, 26, 31, 38, 47, 48, 49, 51, and 55, and of these four produce *good* butter, viz.: Nos. 2, 22, 47 and 49. On the other hand, at least four of the acid species produce decidedly *bad* butter, Nos. 16*i*, 18, 54, and 56, and of the species producing an alkaline reaction five produce *bad* butter, Nos. 27, 31, 38, 48, and 55. All of the other species produce little or no appreciable effect on the butter. Of all the species thus far studied, the one producing the best results and the most desirable aroma in the butter was No. 41, which, while producing a little acid, does not appreciably sour the milk or cream and never either curdles it or even renders it thicker than usual. The experiments, therefore, thus far indicate that the butter aroma has nothing to do with the production of lactic acid.

# FEEDING EXPERIMENT WITH SHEEP.

BY CHAS. D. WOODS AND C. S. PHELPS.

The experiment was undertaken in order to observe the effects of different kinds of food upon the chemical composition of the flesh of sheep, and is a continuation of that reported in the preceding Report* of this Station.

## PLAN OF THE EXPERIMENT.

The plan consisted in selecting a number of sheep of the same breed and age, and as nearly alike as possible, and dividing them into four groups. One group was to be butchered at the beginning of the experiment and the flesh analyzed. The results of the weighings and analyses of this group would serve to indicate more or less accurately the condition of the other animals at the beginning of the experiment. Two other groups were to be fed differently, one upon a wide ration (relatively deficient in protein), the other upon a narrow ration (relatively rich in protein). In the two groups just mentioned, each animal was fed in a separate pen. A fourth group was selected from the remainder of the flock and fed collectively in one pen. This group received the narrow ration. The main object of this part of the test was to observe whether there would be any advantage in feeding in groups rather than in single pens adjoining each other. At the end of the experiment the animals were all to be butchered and as complete analyses of the flesh made as should seem advisable.

## DETAILS OF THE EXPERIMENT.

About the middle of October, 1893, a flock of 38 grade Shropshire lambs of the preceding spring were purchased for the experiments of the winter of 1893–94. They were bred and reared in Vermont by one farmer, and were in medium condition when purchased, although they varied considerably in size. The smallest were excluded from the experiment. The animals were kept in a yard, covering about one-fourth of an acre, and were fed, in addition to the pasturage of the yard, early-cut hay till Nov. 8. At this time they were divided into groups.

* Report of this Station, 1893, pp. 28–42.

Four average animals of quiet dispositions were first selected for digestion experiments on the rations to be fed in the feeding experiments with the other animals. Three groups of five each were then selected for the feeding experiments. Lot A of five, Nos. 13–17, was placed in a large pen preparatory to slaughtering. Two other lots of five each—B, Nos. 20–24, and C, Nos. 25–29, were placed in individual pens. They were fed alike till Nov. 14, being allowed all the good hay they would eat, and each in addition had about one-half pound of ground oats and peas.

Beginning Nov. 14, each animal was allowed 12 ounces of ground oats and peas and 1½ pounds of early-cut hay. On Nov. 16, all of the lambs of lots A, B and C were weighed and individuals were shifted until the total weights for each lot were nearly the same.

Six animals of about the same total weight as the other lots of five each, were also selected from the remainder of the flock and placed in a large pen to be fed collectively. The experiment began Nov. 16. Lot B was fed the wide ration and lot C and the group (D) had the narrow ration. The following table gives the weight of each animal at the beginning of the experiment and the total and average for each lot:

*Weights of Each Sheep and Total and Average Weight of Each Lot at Beginning of the Experiment.*

| Lot (A) Slaughtered. | | Lots Fed in Single Pens. | | | | Group (D) Fed. | |
|---|---|---|---|---|---|---|---|
| Nos. | Nov. 16. | Wide Ration, Lot B. | | Narrow Ration, Lot C. | | Narrow Ration. | |
| | Lbs. | Nos. | Lbs. | Nos. | Lbs. | Nos. | Lbs. |
| 13 | 79.0 | 20 | 59.5 | 25 | 61.5 | 30 | 58.0 |
| 14 | 60.0 | 21 | 75.5 | 26 | 55.8 | 31 | 48.5 |
| 15 | 54.5 | 22 | 55.5 | 27 | 71.3 | 32 | 46.0 |
| 16 | 54.5 | 23 | 59.0 | 28 | 50.5 | 33 | 63.0 |
| 17 | 56.0 | 24 | 56.0 | 29 | 63.5 | 34 | 45.5 |
| — | — | — | — | — | — | 35 | 44.0 |
| Total, | 304.0 | — | 305.5 | — | 302.6 | — | 305.0 |
| Average, | 60.8 | — | 61.1 | — | 60.5 | — | 50.9 |

From this tabulation it will be seen that the total weights of each lot were essentially the same, and that the average weights of the sheep in each lot, except the group, were nearly alike.

The sheep of the group (D) fed collectively were considerably smaller than those of the other lots, six animals weighing about the same as five in each of the other lots. It will be noticed that the individual sheep of each of the lots varied considerably. This was an unfortunate condition, as it probably indicated somewhat similar differences in the general vigor and thriftiness of the sheep.

The five animals intended for slaughter (Lot A) were killed Nov. 16, and were intended to represent as nearly as possible the average condition of the other three lots. The feeding commenced Nov. 16 and continued till March 29 for the two lots (B and C) fed singly, and till April 13 for the group (D). The sheep fed in single pens were separated from each other by only slat partitions, and they seemed quiet and contented throughout the experiment.

TABLE 16.

*Kinds and Amounts of Food in Ration Used for Each Animal in Sheep Feeding Experiment, 1893–94.*

| KIND OF FOOD. | FED FROM NOV. 16 TO MARCH 29, 133 DAYS. | | GROUP D. |
|---|---|---|---|
| | Each Day. | Total for 133 Days. | Daily. |
| *Lot A.* *Sheep Nos. 20–24, Wide Ration.* | Oz. | Lbs. | |
| Corn meal, | 12 | 100 | — |
| Wheat bran, | 4 | 33 | — |
| Hay, | 16 | 133 | — |
| Turnips,* | 4 | 11 | — |
| | 36 | 277 | — |
| *Lot B, and Group Lot D.* *Sheep Nos. 26–29, and Nos. 30–35, Narrow Ration.* | | | |
| Linseed meal, 3 parts, Corn meal, 1 part, } mixture, | 4 | 33 | 20 |
| Oat and pea meal, | 8 | 67 | 40 |
| Wheat bran, | 4 | 33 | 20 |
| Hay, | 16 | 133 | 80 |
| | 32 | 266 | 160 |

* Fed 44 days; Feb. 10 to March 26.

KINDS AND AMOUNTS OF FOOD.

As the animals varied considerably in weight, it was thought best to feed each sheep according to the requirements of its appetite. The sheep were fed on about the same plan as in the experiment of the winter of 1892–93.* Those of the wide ration

* Report of this Experiment Station, 1893, page 28.

(lot B, Nos. 20–24) were fed hay from early-cut mixed grasses, together with corn meal and wheat bran, with a small amount of turnips, during the latter part of the experiment. Those having the narrow ration (lot C, Nos. 25–29) received the same kind of hay, and in addition, corn meal, wheat bran, linseed meal, and ground oats and peas. The group (D) was fed the same kinds of feed as lot C. Two rations, assumed to be normal in quantity, one wide and one narrow, were first prepared and taken as a basis, the total amounts fed being increased or decreased from time to time according to the appetites of the sheep.

Sheep No. 24 of the wide ration and No. 25 of the narrow ration were dropped out during the latter part of the experiment owing to lack of thriftiness, so that the discussion which follows applies to only four sheep in lot B and four in lot C. The amounts fed in the normal ration are shown in table 16 on the opposite page.

TABLE 17.

*Percentage Composition of the Feeding Stuffs Used and the Uneaten Residues in Sheep Feeding Experiment of 1893-94.**

| MATERIALS FED. | Water. | Protein. | Fat. | Nit.-free Ext | Fiber. | Ash. |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| Corn meal, | 12.42 | 10.10 | 4.54 | 70.43 | 1.28 | 1.24 |
| Wheat bran, | 8.90 | 17.34 | 5.23 | 52.95 | 9.91 | 5.67 |
| Linseed mixture, | 10.50 | 30.06 | 5.53 | 43.60 | 5.96 | 4.35 |
| Oat and pea meal, | 11.55 | 23.88 | 2.53 | 52.05 | 6.62 | 3.37 |
| Hay (mixed grasses,) | 8.31 | 11:18 | 3.59 | 40.65 | 31.04 | 5.23 |
| *Uneaten Hay Residue.* | | | | | | |
| Sheep No. 20, | 9.25 | 11.13 | 3.20 | 44.14 | 26.33 | 5.95 |
| Sheep No. 21, | 7.56 | 9.31 | 3.12 | 45.94 | 28.95 | 5.12 |
| Sheep No. 22, | 7.95 | 11.25 | 3.41 | 48.23 | 23.52 | 5.64 |
| Sheep No. 23, | 7.37 | 10.38 | 3.91 | 46.33 | 26.34 | 5.67 |
| Sheep No. 26, | 8.61 | 11.38 | 2.75 | 48.60 | 23.32 | 5.34 |
| Sheep No. 27, | 7.69 | 12.69 | 3.03 | 45.01 | 26.54 | 5.04 |
| Sheep No. 28, | 9.08 | 14.81 | 2.68 | 44.18 | 24.50 | 4.75 |
| Sheep No. 29, | 9.09 | 14.25 | 2.42 | 40.11 | 29.52 | 4.61 |
| Group D, | 8.21 | 13.25 | 2.49 | 39.95 | 30.36 | 5.74 |
| *Uneaten Grain Residues.* | | | | | | |
| Sheep No. 20, | 10.49 | 12.38 | 3.17 | 61.99 | 6.26 | 5.71 |
| Sheep No. 22, | 8.41 | 12.31 | 3.59 | 64.84 | 6.71 | 4.14 |
| Sheep No. 23, | 8.57 | 11.75 | 3.92 | 64.32 | 5.30 | 6.14 |
| Sheep No. 26, | 8.32 | 21.38 | 2.75 | 45.57 | 16.19 | 5.79 |
| Sheep No. 27, | 8.01 | 20.75 | 2.62 | 49.86 | 13.31 | 5.45 |
| Sheep No. 28, | 8.87 | 22.63 | 2.75 | 47.98 | 12.11 | 5.66 |
| Sheep No. 29, | 9.42 | 21.56 | 2.38 | 47.37 | 13.21 | 6.06 |
| Group D, | 8.89 | 19.06 | 3.32 | 46.79 | 13.70 | 8.24 |

* For composition of these feeding stuffs calculated on water-free basis, see pp. 23–25 of this Report.

### PERCENTAGE COMPOSITION OF THE FEEDING STUFFS USED.

Samples of the grain and hay fed in the experiment were selected from time to time for the purpose of learning the composition of the feeds used. These were taken in connection with the digestion experiments, two of which were made on the "narrow" and two on the "wide" ration. The uneaten residues of each animal were also kept separate, the residue of grain being separated from the hay as far as possible.

The composition of the feeds used, and of the residues, is shown in Table 17, which precedes.

### DIGESTIBILITY OF THE RATIONS.

In the sheep-feeding experiment of the winter of 1892–93 the digestibility of the rations was calculated from average coefficients of digestibility of the different fodders, taken largely from the results of American experiments, and in a few cases from German experiments. The digestibility of the fodder is one of the most important factors which bear upon its effect on the animal, whether fed for growth, fattening, or milk. Any one fodder is liable to vary widely in digestibility from the average given in tables of compilations, so that even if the feeds used are analyzed, a source of error is introduced unless the digestibility of the particular ration is also known.

Two digestion experiments were made on both the narrow and the wide ration, two sheep being used in each case. The details of these digestion experiments are given in the papers on digestion experiments with sheep which follows this article.

The percentage digested of each of the constituents of the rations is shown in the following tables:—

TABLE 18.

| Rations Fed Daily. | Oz. | Organic Matter. | Protein. | Fat. | Nit.-free Ext | Fiber. | Ash. |
|---|---|---|---|---|---|---|---|
| *Wide Ration.* | | | | | | | |
| Corn meal, | 12 | | | | | | |
| Wheat bran, | 4 | 69.0 | 55.0 | 68.5 | 76.4 | 55.3 | 23.0 |
| Mixed hay, | 16 | | | | | | |
| *Narrow Ration.* | | | | | | | |
| Corn meal, | 1 | | | | | | |
| Linseed meal, | 3 | | | | | | |
| Wheat bran, | 4 | 71.6 | 73.4 | 70.5 | 74.8 | 62.5 | 29.2 |
| Oat and pea meal, | 8 | | | | | | |
| Mixed hay, | 16 | | | | | | |

It will be readily seen that the narrow ration (relatively rich in protein) was much more thoroughly digested than the wide ration (relatively deficient in protein).

A large number of digestion experiments made in Germany indicate that the presence of large quantities of carbohydrates (starch) in a ration tends to lower the digestibility of the protein and fiber. This experiment points in the same direction. The wide ration had a large proportion of corn meal, which supplied large amounts of starch, while the narrow ration had but a small quantity of corn meal, but was relatively rich in protein. But whether these results are actual or only apparent, neither these experiments, nor those previously made, decide.

## THE RATIONS EATEN.

Table 19, which follows, shows the total amount of hay and grain fed to each sheep for the whole period, the total nutrients and the digestible nutrients and also the averages for each day. The averages are given in heavy type so that the total ration for each sheep can be readily seen. Nos. 20-24 were fed a small quantity of turnips during the latter half of the experiments. These did not enter into the digestion experiments and their digestibility is estimated from the averages of other experiments. Only small quantities were eaten and hence their influence on the ration must have been slight.

The uneaten residues consisted of the coarse parts of the hay, together with some grain. The amounts uneaten were small and it was thought that no great error could be introduced by assuming their digestibility to be the same as that of the entire ration. Table 20 summarizes the total and digestible nutrients eaten by each sheep in the experiments. Wolff's (German) standard for fattening sheep per 75 pounds live weight is also given, and has a nutritive ratio of 1:5.5. The average of 11 experiments with 22 animals, conducted in five experiment stations of the United States is also given and has a nutritive ratio of 1:6.1. The fuel value of each of the rations of the experiment is less than that of the standards. In the experiment the sheep were fed on a basis of 75 pounds live weight. It will be noticed that the narrow ration contained a relatively large amount of protein and is narrower than either of the standards, and that the wide ration contains a relatively small amount of protein and is much wider than either of the standards.

TABLE 19.

*Estimated Total and Digestible Nutrients in Food Eaten by Each Animal in Sheep Feeding Experiment, 1893–94.*

| Lot B. | Total of Feeds. | Total Nutrients. | | | | Digestible Nutrients. | | |
|---|---|---|---|---|---|---|---|---|
| | | Protein. | Fat. | Nit.-free Ext | Fiber. | Protein. | Fat. | Carbohydrates. |
| WIDE RATION. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| *Sheep No. 20.* | | | | | | | | |
| Corn meal, | 97.8 | 15.6 | 6.1 | 86.2 | 4.5 | — | — | — |
| Wheat bran, | 32.6 | | | | | | | |
| Hay, | 130.4 | 14.6 | 4.7 | 53.8 | 40.6 | — | — | — |
| Turnips, | 11.0 | | | | | | | |
| Total furnished, | 271.8 | 30.2 | 10.8 | 140 0 | 45.1 | 16.7 | 7.4 | 131.5 |
| Uneaten residue, | 4.4 | .5 | .1 | 2.6 | .4 | .3 | .1 | 2.2 |
| Total eaten in 133 days, | 267.4 | 29.7 | 10.7 | 137.4 | 44.7 | 16.4 | 7.3 | 129.3 |
| Average per day, | — | .223 | .080 | 1.033 | .336 | .123 | .055 | .971 |
| *Sheep No. 21.* | | | | | | | | |
| Corn meal, | 105.3 | 16.7 | 6.6 | 92.8 | 4.8 | — | — | — |
| Wheat bran, | 35.1 | | | | | | | |
| Hay, | 140.5 | 15.8 | 5.0 | 57.9 | 43.7 | — | — | — |
| Turnips, | 11.0 | | | | | | | |
| Total furnished, | 291.9 | 32.5 | 11.6 | 150.7 | 48.5 | 18.0 | 7.9 | 141.5 |
| Uneaten residue, | 2.7 | .3 | .1 | 1.2 | .8 | .1 | .1 | 1.4 |
| Total eaten in 133 days, | 289.2 | 32.2 | 11.5 | 149.5 | 47.7 | 17.9 | 7.8 | 140.1 |
| Average per day, | — | .242 | .086 | 1.124 | .359 | .135 | .059 | 1.053 |
| *Sheep No. 22.* | | | | | | | | |
| Corn meal, | 99.4 | 15.8 | 6.2 | 87.6 | 4.6 | — | — | — |
| Wheat bran, | 33.2 | | | | | | | |
| Hay, | 132.5 | 14.9 | 4.8 | 54.7 | 41.1 | — | — | — |
| Turnips, | 11.0 | | | | | | | |
| Total furnished, | 276.1 | 30.7 | 11.0 | 142.3 | 45.7 | 17.0 | 7.5 | 133.6 |
| Uneaten residue, | 5.3 | .6 | .2 | 3.2 | 0.6 | .4 | .1 | 2.7 |
| Total eaten in 133 days, | 270.8 | 30.1 | 10.8 | 139.1 | 45.1 | 16.6 | 7.4 | 130.9 |
| Average per day, | — | .226 | .081 | 1.046 | .339 | .125 | .056 | .984 |
| *Sheep No. 23.* | | | | | | | | |
| Corn meal, | 91.7 | 14.6 | 5.8 | 80.8 | 4.2 | — | — | — |
| Wheat bran, | 30 6 | | | | | | | |
| Hay, | 122 3 | 13.8 | 4.4 | 50.5 | 38.1 | — | — | — |
| Turnips, | 11.0 | | | | | | | |
| Total furnished, | 255.6 | 28.4 | 10.2 | 131.3 | 42.3 | 15.7 | 7.0 | 123.3 |
| Uneaten residue, | 5.8 | .7 | .2 | 3.4 | .8 | .4 | .2 | 3.0 |
| Total eaten in 133 days, | 249.8 | 27.7 | 10.0 | 127.9 | 41.5 | 15.3 | 6.8 | 120.3 |
| Average per day, | — | .208 | .075 | .962 | .312 | .115 | .051 | .905 |

TABLE 19.—(*Continued.*)

| LOT C. | Total of Feeds. | TOTAL NUTRIENTS. Pro-tein. | Fat. | Nit.-free Ext | Fiber. | DIGESTIBLE NUTRIENTS. Pro-tein. | Fat. | Carbo-hy-drates. |
|---|---|---|---|---|---|---|---|---|
| NARROW RATION. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| *Sheep No. 26.* | | | | | | | | |
| Lin. meal, 3 parts, Corn meal, 1 part, } mix., | 34.1 | | | | | | | |
| Wheat bran, - - - | 34.1 | 32.5 | 5.4 | 68.4 | 9.9 | — | — | — |
| Oat and pea meal, - | 68.1 | | | | | | | |
| Hay, - - - - | 136.3 | 15.2 | 4.9 | 55.4 | 42.3 | — | — | — |
| Total furnished, - | 272.6 | 47.7 | 10.3 | 123.8 | 52.2 | 35.0 | 7.3 | 125.2 |
| Uneaten residue, - - | 2.9 | .4 | .1 | 1.4 | .6 | .3 | .1 | 1.4 |
| Total eaten in 133 days, | 269.7 | 47.3 | 10.2 | 122.4 | 51.6 | 34.7 | 7.2 | 123.8 |
| Average per day, - - | — | .356 | .077 | .920 | .388 | .261 | .054 | .931 |
| *Sheep No. 27.* | | | | | | | | |
| Lin. meal, 3 parts, Corn meal, 1 part, } mix., | 34.1 | | | | | | | |
| Wheat bran, - - | 34.1 | 32.5 | 5.4 | 68.4 | 9.9 | — | — | — |
| Oat and pea meal, - | 68.1 | | | | | | | |
| Hay, - - - - | 136.3 | 15.2 | 4.9 | 55.4 | 42 3 | — | — | — |
| Total furnished, - | 272.6 | 47.7 | 10.3 | 123.8 | 52.2 | 35.0 | 7.3 | 125.2 |
| Uneaten residue, - - | 2.4 | .4 | .1 | 1.1 | .6 | .3 | .1 | 1.2 |
| Total eaten in 133 days, | 270.2 | 47.3 | 10.2 | 122.7 | 51.6 | 34.7 | 7.2 | 124.0 |
| Average per day, - - | — | .356 | .077 | .923 | .388 | .261 | .054 | .932 |
| *Sheep No. 28.* | | | | | | | | |
| Lin. meal, 3 parts, Corn meal, 1 part, } mix., | 33.3 | | | | | | | |
| Wheat bran, - - - | 33.3 | 31.7 | 5.2 | 66.7 | 9.7 | — | — | — |
| Oat and pea meal, - | 66.5 | | | | | | | |
| Hay, - - - - | 133.0 | 14.9 | 4.8 | 54.0 | 41.3 | — | — | — |
| Total furnished, - | 266.1 | 46.6 | 10.0 | 120.7 | 51.0 | 34.2 | 7.1 | 122.2 |
| Uneaten residue, - - | 2.4 | .5 | .1 | 1.1 | .4 | .3 | — | 1.1 |
| Total eaten in 133 days, | 263.7 | 46.1 | 9.9 | 119.6 | 50.6 | 33.9 | 7.1 | 121.1 |
| Average per day, - - | — | .347 | .074 | .899 | .381 | .255 | .053 | .910 |
| *Sheep No. 29.* | | | | | | | | |
| Lin. meal, 3 parts, Corn meal, 1 part, } mix., | 34.7 | | | | | | | |
| Wheat bran, - - - | 34.7 | 33.0 | 5.5 | 69.7 | 10.1 | — | — | — |
| Oat and pea meal, - | 69.4 | | | | | | | |
| Hay, - - - - | 138.9 | 15.5 | 5.0 | 56.5 | 43.1 | — | — | — |
| Total furnished, - | 277.7 | 48.5 | 10.5 | 126.2 | 53.2 | 35.6 | 7.4 | 127.6 |
| Uneaten residue, - - | 1.3 | .2 | — | .6 | .3 | .2 | — | .6 |
| Total eaten in 133 days, | 176.4 | 48.3 | 10.5 | 125.6 | 52.9 | 35.4 | 7.4 | 127.0 |
| Average per day, - - | — | .363 | .079 | .944 | .398 | .266 | .056 | .955 |

TABLE 19.—(*Continued.*)

| Group D. | Total of Feeds. | Total Nutrients. | | | | Digestible Nutrients. | | |
|---|---|---|---|---|---|---|---|---|
| | | Protein. | Fat. | Nit.-free Ext | Fiber. | Protein. | Fat. | Carbohydrates. |
| *Six Sheep, Narrow Ration.* | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| Lin. meal, 3 parts, } mix., Corn meal, 1 part, } | 214.5 | | | | | | | |
| Wheat bran, - - | 214.5 | 204.1 | 33.9 | 430.4 | 62.5 | — | — | — |
| Oat and pea meal, - | 429.0 | | | | | | | |
| Hay, - - - - - | 858.0 | 95.9 | 30.8 | 348.8 | 266.3 | — | — | — |
| Total furnished, - | 1716.0 | 300.0 | 64.7 | 779.2 | 328.8 | 220.2 | 45.8 | 788.4 |
| Uneaten residue, - - | 7.6 | 1.1 | .2 | 3.2 | 2.0 | .8 | .1 | 3.7 |
| Total eaten in 146 days, | 1709.4 | 298.9 | 64.5 | 776.0 | 326.8 | 219.4 | 45.7 | 784.7 |
| Av. per day per group, | — | 2.047 | .442 | 5.315 | 2.239 | 1.503 | .313 | 5.375 |
| Av. per day per head, - | — | .341 | .074 | .886 | .373 | .251 | .052 | .896 |

TABLE 20.

*Average of Total and Digestible Nutrients Eaten Daily by Each Animal in Sheep Feeding Experiment of 1893–94.—Summary Standard Rations for 75 Pounds, Live Weight.*

| Sheep Number. | Total Nutrients Eaten. | | | | Digestible Nutrients.* | | | |
|---|---|---|---|---|---|---|---|---|
| | Protein. | Fat. | Nit.-free Ext. | Fiber. | Protein. | Fat. | Carbohydrates. | Fuel Val. |
| *Wide Ration.* | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Cal. |
| No. 20, - - | .223 | .080 | 1.033 | .336 | .123 | .055 | .971 | 2265 |
| No. 21, - - | .242 | .086 | 1.124 | .359 | .135 | .059 | 1.053 | 2466 |
| No. 22, - - | .226 | .081 | 1.046 | .339 | .125 | .056 | .984 | 2300 |
| No. 23, - - | .208 | .075 | .962 | .312 | .115 | .051 | .905 | 2205 |
| Average, - - | .23 | .08 | 1.04 | .34 | .13 | .06 | .98 | 2320 |
| *Narrow Ration.* | | | | | | | | |
| No. 26, - - | .356 | .077 | 9.20 | .388 | .261 | .054 | .931 | 2445 |
| No. 27, - - | .356 | .077 | 9.23 | .388 | .261 | .054 | .932 | 2445 |
| No. 28, - - | .347 | .074 | 8.99 | .381 | .255 | .053 | .910 | 2390 |
| No. 29, - - | .363 | .079 | 9.44 | .398 | .266 | .056 | .955 | 2505 |
| Average, - - | .36 | .08 | .92 | .39 | .26 | .05 | .93 | 2425 |
| *Group D.—Narrow Ration.* | | | | | | | | |
| Average per head, | .341 | .074 | .886 | .373 | .251 | .052 | .896 | 2355 |
| *Standard Rations per 75 lbs. Live Weight.* | | | | | | | | |
| German,† - - | — | — | — | — | .23 | .04 | 1.14 | 2715 |
| American, - - | — | — | — | — | .20 | .07 | 1.08 | 2675 |

* The nutritive ratio of the wide ration is 1:8.7 and that of the narrow ration 1:4.1; that of the German standard is 1:5.5, and the American 1:6.2.

† See explanation, p. 97.

RESULTS OF THE EXPERIMENT.

At the end of the experiment, March 28, the animals were all sheared and the weights of the wool were taken. On March 29 the animals were all butchered and the internal organs and carcasses were weighed, and the meat sent to the laboratory for analysis.

The statistics at the time of butchering are given in Table 21.

TABLE 21.

*Sheep Feeding Experiment, 1893-94.—Statistics of Animals.*

| Sheep No. | Live Weight.* | | | Dressed Weight. | Weight of Organs, Etc. | | | | | Wool. |
|---|---|---|---|---|---|---|---|---|---|---|
| | At Begin'g of Expt. Nov. 16. | At End of Expt. March 28. | Increase in 133 Days. | | Lungs and Windpipe. | Liver. | Heart and Aorta. | Kidneys. | Intestinal Fat. | |
| *Lot A.* | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| 13, - - - | 79.0 | — | — | 31.7 | 1.09 | 1.22 | .38 | .21 | 1.38 | — |
| 14, - - - | 60.0 | — | — | 25.9 | .94 | .91 | .25 | .16 | 1.66 | — |
| 15, - - - | 54.5 | — | — | 21.6 | .69 | 1.03 | .25 | .13 | 1.00 | — |
| 16, - - - | 54.5 | — | — | 23.1 | .72 | .81 | .25 | .16 | 1.16 | — |
| 17, - - - | 56.0 | — | — | 22.9 | .72 | .69 | .28 | .14 | 1.56 | — |
| Average, - | **60.8** | — | — | **25.0** | **.83** | **.93** | **.28** | **.16** | **1.35** | — |
| *Lot B.* Wide Ration. | | | | | | | | | | |
| 20, - - - | 59.5 | 82.5 | 23.0 | 34.4 | 1.41 | 1.41 | .41 | .19 | 2.75 | 6.66 |
| 21, - - - | 75.5 | 100.0 | 24.5 | 42.1 | 1.75 | 1.56 | .41 | .21 | 2.91 | 8.44 |
| 22, - - - | 55.5 | 76.1 | 21.1 | 31.4 | 1.47 | 1.63 | .38 | .21 | 2.41 | 5.94 |
| 23, - - - | 59.0 | 78.3 | 19.3 | 34.9 | 1.28 | 1.66 | .41 | .19 | 2.09 | 7.19 |
| Average, - | **62.4** | **84.4** | **22.0** | **35.7** | **1.48** | **1.57** | **.40** | **.20** | **2.54** | **7.06** |
| *Lot C.* Narrow Ration. | | | | | | | | | | |
| 26, - - - | 55.8 | 89.4 | 33.6 | 40.0 | 1.59 | 1.34 | .50 | .20 | 1.81 | 4.53 |
| 27, - - - | 71.3 | 86.4 | 15.1 | 38.3 | 1.69 | 1.25 | .34 | .22 | 2.59 | 5.75 |
| 28, - - - | 50.5 | 80.3 | 29.8 | 36.7 | 1.19 | 1.06 | .44 | .18 | 2.22 | 5.19 |
| 29, - - - | 63.5 | 91.3 | 27.8 | 37.9 | 1.66 | 1.34 | .38 | .20 | 2.00 | 6.44 |
| Average, - | **60.3** | **86.9** | **26.6** | **38.2** | **1.53** | **1.25** | **.42** | **.20** | **2.16** | **5.48** |
| *Group D.*† *6 Sheep* Narrow Ration. | | | | | | | | | | |
| Avg. per head, - | **50.8** | **77.2** | **26.3** | **33.9** | **1.46** | **1.03** | **.37** | — | **2.04** | **4.61** |

* Including wool. † Fed 146 days.

Lot A (Nos. 13-17) that had been killed November 16, was used as a basis for observing the effect of the ration on the composition of the meat. From the weights of the animals at the beginning and at the end of the experiment it will be seen that there was an increase in the live weight, including the growth of wool from 19.3 to 24.5 pounds in the case of the wide

ration lot (B), and from 15 1 to 33.6 pounds in the case of the narrow ration lot (C), while group D made an average gain of 26.6 pounds.

The average live weight of the animals of lot A (60.8 pounds), which were killed and analyzed at the beginning of the experiment, was practically the same as that of the two lots fed in single pens lots B and C (62.4 and 60.3 pounds). The average dressed weight of lot A was 25.0 pounds. The average dressed weight of the wide ration lot was 35.7, and of the narrow ration lot 38.2 pounds. If it is assumed that the animals of lots B and C would have dressed, at the start, the same as the average of lot A, the gain in dressed weight would have been 10.7 pounds for the wide ration lot and 13.2 pounds for the narrow ration lot.

There was practically no difference between the weights of the lungs, the hearts, and the kidneys of the narrow ration and the wide ration lots. The livers were one-third of a pound heavier in case of the wide ration sheep. In this respect the experiment differs from a similar one made the previous winter where the livers of the narrow ration lot were one-tenth of a pound heavier than in the wide ration lot.

The animals slaughtered at the beginning of the experiment had an average of 1.35 pounds of intestinal and caul fat. The narrow ration sheep gave an average increase of .8 pounds and the wide ration sheep 1.2 pounds of intestinal and caul fat.

The sheep were not sheared at the beginning of the experiment and hence it is not possible to get the increase of wool during the test. If we assume that the growth of wool was the same in the two lots at the start, the wide ration sheep must have made a much larger growth of wool, as the average weight of wool at the end of the experiment is 2.6 pounds greater for the wide ration sheep than it is for the narrow ration sheep. In the experiment of the previous winter where the sheep were sheared at the start, the narrow ration sheep grew heavier fleeces.

## CHEMICAL COMPOSITION OF THE FLESH.

The flesh of the sheep of the narrow ration and the wide ration lots was analyzed. In each case the right side was used for analysis. The flesh of the entire side was carefully separated from the bones and then finely cut in a sausage machine. After thoroughly mixing the entire mass a small sample was taken and prepared for analysis. The results of the analyses calculated

both on water-free (dry matter) and fresh substance (flesh) are given in table 22, which follows.

TABLE 22.

*Percentage Composition of Flesh (Edible Portion) of Animals in Sheep Feeding Experiment of 1893–94.*

| | Calculated on Water-free Basis. | | | Calculated to Water Content of Flesh. | | | |
|---|---|---|---|---|---|---|---|
| | Protein. | Fat. | Ash. | Water. | Protein. | Fat. | Ash. |
| *At Beginning of Experiment.* | % | % | % | % | % | % | % |
| Sheep No. 13, - - - - | 41.93 | 55.89 | 2.18 | 58.19 | 17.53 | 23.37 | .91 |
| Sheep No. 14, - - - - | 33.56 | 64.63 | 1.81 | 52.41 | 15.97 | 30.76 | .86 |
| Sheep No. 15, - - - - | 39.24 | 58.68 | 2.08 | 57.24 | 16.78 | 25.09 | .89 |
| Sheep No. 16, - - - - | 33.87 | 64.26 | 1.87 | 53.47 | 15.76 | 29.90 | .87 |
| Sheep No. 17, - - - - | 34.38 | 63.71 | 1.91 | 54.53 | 15.63 | 28.97 | .87 |
| Average, - - - - | **36.60** | **61.43** | **1.97** | **55.17** | **16.33** | **27.62** | **.88** |
| *Wide Ration.* | | | | | | | |
| Sheep No. 20, - - - - | 30.03 | 68.35 | 1.62 | 50.58 | 14.84 | 33.78 | .80 |
| Sheep No. 21, - - - - | 34.23 | 63.86 | 1.91 | 54.90 | 15.44 | 28.80 | .86 |
| Sheep No. 22, - - - - | 33.16 | 65.04 | 1.80 | 51.06 | 16.23 | 31.83 | .88 |
| Sheep No. 23, - - - - | 32.97 | 65.32 | 1.71 | 51.53 | 15.98 | 31.66 | .83 |
| Average, - - - - | **32.60** | **65.64** | **1.76** | **52.02** | **15.62** | **31.52** | **.84** |
| *Narrow Ration.* | | | | | | | |
| Sheep No. 26, - - - - | 38.57 | 59.21 | 2.22 | 56.36 | 16.83 | 25.84 | .97 |
| Sheep No. 27, - - - - | 33.69 | 64.47 | 1.84 | 52.24 | 16.09 | 30.79 | .88 |
| Sheep No. 28, - - - - | 26.59 | 71.88 | 1.53 | 47.15 | 14.05 | 37.99 | .81 |
| Sheep No. 29, - - - - | 44.53 | 53.03 | 2.44 | 60.59 | 17.55 | 20.90 | .96 |
| Average, - - - - | **35.84** | **62.15** | **2.01** | **54.09** | **16.13** | **28.88** | **.91** |

In table 23, on the following page, are given the actual weights of nutrients, protein, fat, etc., in the total flesh of each animal of lots A, B and C. The pounds of nutrients, as shown in the last five columns at the right were obtained by multiplying the weight of flesh (edible portion) by the percentage composition of the flesh as given in table 22. The average percentage of fat in the dry matter was 2.6 higher in the case of the wide ration than with the narrow ration lot of sheep, while the average of protein was .5 per cent. higher in case of the narrow ration lot.

The ratio between the percentages of protein and fat in the dry matter at the beginning of the experiment was 1 to 1.7, and at the end was 1 to 1.8 for the narrow ration lot, and 1 to 2 for the wide ration lot. This shows that the sheep increased in relative fatness from the beginning of the experiment in each lot, and that the relative fatness was somewhat more in case of the wide ration lot.

TABLE 23.

*Weights of Flesh and Nutrients in Flesh of Animals in Sheep Feeding Experiment, 1893–94.*

| | Live Weight. | Dressed Weight, without Kidneys and Hoofs. | Refuse (Bone). | Edible Portion (Flesh). | In Edible Portion (Flesh). | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Water. | Water-free Substance. | Water-free Sub. | | |
| | | | | | | | Protein. | Fat. | Ash. |
| *Beginning of Expt.* | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| Sheep No. 13, - | 79.0 | 30.76 | 6.86 | 23.90 | 13.90 | 10.00 | 4.19 | 5.59 | .217 |
| Sheep No. 14, - | 60.0 | 24.94 | 4.44 | 20.50 | 10.74 | 9.76 | 3.27 | 6.30 | .176 |
| Sheep No. 15, - | 54.5 | 20.58 | 4.60 | 15.98 | 9.15 | 6.83 | 2.68 | 4.01 | .142 |
| Sheep No. 16, - | 54.5 | 22.26 | 5.06 | 17.20 | 9.20 | 8.00 | 2.71 | 5.14 | .150 |
| Sheep No. 17, - | 56.0 | 21.28 | 4.52 | 16.76 | 9.14 | 7.62 | 2.62 | 4.86 | .146 |
| Average, - | **60.8** | **23.97** | **5.10** | **18.87** | **10.43** | **8.44** | **3.09** | **5.18** | **.166** |
| *Wide Ration.* | | | | | | | | | |
| Sheep No. 20, - | 82.5 | 33.56 | 5.96 | 27.60 | 13.96 | 13.64 | 4.10 | 9.32 | .221 |
| Sheep No. 21, - | 100.0 | 40.00 | 7.26 | 32.74 | 17.96 | 14.78 | 4.06 | 9.43 | .282 |
| Sheep No. 22, - | 76.1 | 29.72 | 6.04 | 23.68 | 14.35 | 9.33 | 3.84 | 7.54 | .208 |
| Sheep No. 23, - | 78.3 | 32.68 | 5.18 | 27.50 | 14.17 | 13.33 | 4.39 | 8.71 | .228 |
| Average, - | **84.4** | **33.99** | **6.11** | **27.88** | **15.11** | **12.77** | **4.09** | **8.75** | **.245** |
| *Narrow Ration.* | | | | | | | | | |
| Sheep No. 26, - | 89.4 | 37.66 | 6.38 | 31.28 | 17.63 | 13.65 | 5.26 | 8.08 | .303 |
| Sheep No. 27, - | 86.4 | 36.88 | 6.44 | 30.44 | 15.90 | 14.54 | 4.90 | 9.37 | .268 |
| Sheep No. 28, - | 80.3 | 34.10 | 4.44 | 29.66 | 13.98 | 15.68 | 4.16 | 11.27 | .240 |
| Sheep No. 29, - | 91.3 | 35.26 | 6.28 | 28.98 | 17.56 | 11.42 | 5.09 | 6.06 | .277 |
| Average, - - | **86.9** | **35.98** | **5.89** | **30.09** | **16.27** | **13.82** | **4.85** | **8.69** | **.272** |

The average differences in composition are pointed out in the following table:

*Differences in Weights of Nutrients with Different Rations.*

| LOT B (NARROW). LOT C (WIDE). | Edible Portion (Flesh). | In Edible Portion (Flesh). | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Water-free Substance. | In Water-free Substance. | | |
| | | | | Protein. | Fat. | Ash. |
| *Increase over Beginning of Experiment.* | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| Wide ration group, average of 4 animals, | **9.01** | **4.68** | **4.33** | **1.00** | **3.57** | **.08** |
| Narrow ration group, average of 4 animals, - - - - - - - | **11.22** | **5.84** | **5.38** | **1.76** | **3.51** | **.10** |
| Increase of narrow ration over wide ration group, - - - - - - | 2.21 | 1.16 | 1.05 | .76 | –.06 | .02 |

The increase in dry matter, water and protein was to have been expected from the percentage composition.

## SUMMARY.

*The experiment was undertaken in order to observe the effects of different kinds of food upon the chemical composition of the flesh of sheep. The plan consisted each year in selecting a number of sheep of the same breed and age, and as nearly alike as possible, and dividing them into three groups. One group was butchered at the beginning of the experiment and the flesh analyzed. The results of the weighings and analyses of this group served to indicate more or less accurately the condition of the other animals at the beginning of the experiment. The two other groups were fed differently, one upon a wide ration relatively deficient in protein, the other upon a narrow ration relatively rich in protein. At the end of the experiment the animals were all butchered and the flesh analyzed. The experiment has been continued through two years, with no very decisive results. That food determines to a great extent the character and chemical composition of the flesh is made clear, but the animals made so little growth that it is unwise to draw definite conclusions of a practical nature from the results of the experiments.*

*The tables which follow give the condensed statistics of the experiments for two years.*

*Summary of Daily Rations Fed, and Averages of Digestible Nutrients Eaten, and Gain in Live and Dressed Weights of Animals.*

| | Digestible Nutrients in Food Actually Eaten. | | | | Increase. | | |
|---|---|---|---|---|---|---|---|
| | Total Organic Matter. | Protein. | Fat. | Carbohydrates. | Fuel Value. | Live wgt., includ'g fleece. | Dressed Wgt. |
| | Lbs. | Lbs. | Lbs. | Lbs. | Cal. | Lbs. | Lbs. |
| Wide ration, 1893, - - - | 1.92 | .23 | .09 | 1.60 | 3785 | .27 | .16 |
| Wide ration, 1894, - - - | 1.17 | .13 | .06 | .98 | 2320 | .16 | .08 |
| Narrow ration, 1893, - - - | 1.90 | .39 | .06 | 1.45 | 3675 | .32 | .19 |
| Narrow ration, 1894, - - - | 1.24 | .26 | .05 | .93 | 2425 | .20 | .10 |
| *To produce a gain of 1 lb., Live Wgt.* | | | | | | | |
| Wide ration, 1893, - - - | 6.99 | .82 | .33 | 5.84 | 14000 | 1.00 | .6 |
| Wide ration, 1894, - - - | 7.31 | .81 | .38 | 6.13 | 14500 | 1.00 | .5 |
| Narrow ration, 1893, - - - | 6.02 | 1.23 | .19 | 4.60 | 11500 | 1.00 | .6 |
| Narrow ration, 1894, - - - | 6.20 | 1.30 | .25 | 4.65 | 12100 | 1.00 | .5 |
| *To produce a gain of 1 lb., Drs'd Wgt.* | | | | | | | |
| Wide ration, 1893, - - - | 11.74 | 1.38 | .55 | 9.81 | 23600 | 1.7 | 1.0 |
| Wide ration, 1894, - - - | 14.62 | 1.62 | .76 | 12.26 | 29000 | 2.0 | 1.0 |
| Narrow ration, 1893, - - - | 10.23 | 2.10 | .32 | 7.81 | 19300 | 1.7 | 1.0 |
| Narrow ration, 1894, - - - | 12.40 | 2.60 | .50 | 9.30 | 24300 | 2.0 | 1.0 |

*Percentage Composition of Flesh, Edible Portion of Animals in Sheep Feeding Experiments of 1893 and 1894.*

| | Calculated on Water-free Basis. | | | Calculated to Water Content of Flesh. | | | |
|---|---|---|---|---|---|---|---|
| | Protein. | Fat. | Ash. | Water. | Protein. | Fat. | Ash. |
| *Beginning of Experiment.* | % | % | % | % | % | % | % |
| 1893, - - - - - | 41.4 | 56.1 | 2.5 | 58.4 | 17.2 | 23.4 | 1.0 |
| 1894, - - - - - | 36.6 | 61.4 | 2.0 | 55.2 | 16.3 | 27.6 | .9 |
| *Wide Ration.* | | | | | | | |
| 1893, - - - - - | 34.9 | 63.2 | 1.9 | 57.3 | 14.9 | 27.0 | .8 |
| 1894, - - - - - | 32.6 | 65.6 | 1.8 | 52.0 | 15.6 | 31.5 | .9 |
| *Narrow Ration.* | | | | | | | |
| 1893, - - - - - | 36.5 | 61.5 | 2.0 | 58.8 | 15.0 | 25.4 | .8 |
| 1894, - - - - - | 35.8 | 62.2 | 2.0 | 54.1 | 16.1 | 28.9 | .9 |

*Differences in Weights of Nutrients with Different Rations.*

| | Edible Portion (Flesh). | In Edible Portion (Flesh). | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Water-free Substance. | In Water-free Substance. | | |
| | | | | Protein. | Fat. | Ash. |
| | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. | Lbs. |
| Wide ration group, Aug. 5, animals, 1893, - - - - - - - | 12.12 | 6.72 | 5.44 | 1.24 | 4.15 | .05 |
| Wide ration group, Aug. 5, animals, 1894, - - - - - - - | 9.01 | 4.68 | 4.33 | 1.00 | 3.57 | .08 |
| Narrow ration group, Aug. 4, animals, 1893, - - - - - - | 14.38 | 8.57 | 5.81 | 1.64 | 4.11 | .06 |
| Narrow ration group, Aug. 4, animals, 1894, - - - - - - | 11.22 | 5.84 | 5.38 | 1.76 | 3.51 | .10 |
| Increase of narrow ration over wide ration group, 1893, - - - | 2.22 | 1.85 | .37 | .40 | −.04 | .01 |
| Increase of narrow ration over wide ration group, 1894, - - - | 2.21 | 1.16 | 1.05 | .76 | −.06 | .02 |

# DIGESTION EXPERIMENTS WITH SHEEP.

BY C. S. PHELPS AND CHAS. D. WOODS.

It is a matter of every-day experience that only a part of the food eaten is actually used by the animal. It is, therefore, of importance in cattle feeding to have a knowledge, not only of the chemical composition of a given food, but of the amounts of the nutrients which are capable of being assimilated. It is not so much what an animal eats, as that which it digests,* that is actually turned to account.

Many analyses have been made of the different materials commonly used for food for cattle, and we have a fairly good knowledge of their composition. A good many experiments upon the digestibility of the different feeding stuffs have been made, but these are necessarily much less in number, and also less accurate than the analyses. Considering the short time that the experiment stations have been in operation in this country, the number of digestion experiments upon American feeding stuffs is quite considerable, but by far the larger number of experiments of this kind have been made in Europe and especially in Germany. Just as it had been of great practical importance to make large numbers of analyses in order that we may know the average composition of American feeding stuffs, so it is important to have a large number of accurately conducted digestion experiments upon American feeding materials. The results already obtained are in many instances more valuable for our conditions than are those of the much larger number of German experiments.

Partly to add to the stock of knowledge upon this important subject and partly because of the need of the results for use in connection with its feeding experiments, the Station began a year ago a series of digestion experiments with sheep.

* The word digestibility as commonly used has more than one meaning. People often speak of one food as being more digestible than another, when they mean it is more quickly or easily digested. As here used, the term digestibility means the proportion of any given food or food constituent which is digested under usual conditions, without regard to the length of time or the ease of digestion.

## DIGESTION EXPERIMENTS—HOW CONDUCTED.

A digestion experiment is usually managed as follows: Selected animals are fed with the kind or kinds of feeding stuffs to be tested. The feeding stuffs are carefully analyzed. A weighed portion is fed, care being taken to see that none is wasted, and that all the uneaten residues are weighed and analyzed. In this way the exact weights of protein, fat, fiber, nitrogen-free extract and ash eaten are ascertained.* The solid excrement of the animal contains the undigested residues. This is carefully collected, dried, weighed and analyzed, and the amounts of undigested protein, fat, fiber, nitrogen-free extract and ash contained in it are found. The difference between the amounts found in the undigested residues and the amounts contained in the food eaten is taken as a measure of the amounts of the various nutrients which have been digested and assimilated by the animals.

While such an experiment seems comparatively simple, it is surrounded by a number of difficulties which make the work laborious and tend to make the results somewhat uncertain.

## INFLUENCE OF THE ANIMAL UPON DIGESTIBILITY.

The results of digestion experiments in Germany warrant the following general conclusions upon the influence of species, breed, etc., upon digestibility of feeding stuffs.

*Influence of Kind of Animals.*—All ruminants, such as cows, oxen, sheep and goats, seem to digest practically the same amount of protein, fat, nitrogen-free extract and fiber from the same kind of food. In general, horses digest less of the food constituents than do ruminants. This is especially true of the fiber and fat in the hays and grasses.

*Influence of Breed.*—The influence of breed upon digestibility has been studied with sheep, but no differences due to breed have been found. In general, it is probably true that different breeds of animals of the same species digest practically the same amounts of nutrients of the same food.

*Influence of the Individual.*—Individual differences have always been observed. The variation is quite wide, and on this account the results with the influences of kinds and breed of animals are somewhat obscured, variations in amounts digested by different

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* For explanation of constituents and uses of feeding stuffs, see pp. 43 and 44 of this Report.

individual animals of the same species and breed being wider than most variations in different species.

*Influence of Age.*—The few experiments (principally with sheep) tried indicate very little difference, if any, due to age.

### EXPERIMENTS HERE REPORTED.

From the above it will be seen that differences due to age, breed and species of ruminants are slight. The digestibility of a feed by a sheep can be taken as a tolerably correct measure of its digestibility by a cow or steer. As sheep are easier to experiment with than are larger animals, and as many of the feeding experiments by the Station are with sheep, they have been employed in the digestion experiments which are here reported upon.

The pens for the animals are similar to those devised by the Maine Experiment Station* except that the partitions and sides were made of half-inch iron pipe. The pen for each animal is about five feet square and has at one side a narrow stall in which the sheep is confined during the part of the experiment in which the feces are collected. The mangers are arranged so as to prevent loss of food by scattering. The rubber-lined bags for collecting the feces and the harness used to hold them in place are quite similar to those used by the Maine Station.

Each experiment lasted twelve days. The first seven days were given to preliminary feeding, during which the feces were not collected and each animal had the run of its pen. At the end of the first seven days the sheep were placed in the narrow stall and the rubber-lined bags for collecting the feces were attached. The whole of the feces was collected during the last five days of the experiment, and was removed twice daily from the bags and placed in the drying apparatus. Each half day's portion of the feces was dried by itself, put in a glass jar and sent to the laboratory for analyses.

The details of the experiments follow.

### DIGESTION EXPERIMENT NO. I.

*Wheat bran, corn meal and hay.*

Two grade Shropshire wethers of preceding spring. Experiment began January 11, 1894, and ended January 23, 1894. Feces collected for five days from January 18 at 1:30 P. M. to January 23 at 1:30 P. M.

* Report Maine Agricultural Experiment Station, 1891, pp. 25-28.

The amounts fed daily were as follows: Wheat bran, 4 ounces; corn meal, 12 ounces; hay, 1 pound, being the wide ration used in the sheep feeding experiments described on page 94 of this Report. With sheep D the experiment was apparently normal throughout. Sheep B had a slight tendency to diarrhœa toward the end of the experiment. This may account for the larger weight of feces in the case of B and the consequent lower coefficients of digestion.

Tables 23 and 24, which follow, give the details of the experiment.

TABLE 23.

*Composition of Feeding Stuffs and Feces.*

| Kind of Material. | Lab'ty No. | Water. | Protein. N×6.25 | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuffs.* | | % | % | % | % | % | % | % |
| Bran,* | 1301 | 9.2 | 17.1 | 5.4 | 52.7 | 10.2 | 5.4 | 85.4 |
| Corn meal,* | 1300 | 12.4 | 10.2 | 4.3 | 70.6 | 1.3 | 1.2 | 86.4 |
| Hay,* | 1325 | 8.8 | 10.9 | 3.7 | 40.3 | 31.1 | 5.2 | 86.0 |
| *Feces.* | | | | | | | | |
| Sheep B, | 1307 | 8.7 | 15.2 | 4.2 | 38.8 | 24.1 | 9.0 | 82.3 |
| Sheep D, | 1308 | 8.5 | 14.2 | 3.7 | 41.7 | 22.9 | 9.0 | 82.5 |

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 24.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | *Grams. | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Bran, | 567 | 97 | 31 | 299 | 58 | 31 | 485 |
| Corn meal, | 1701 | 173 | 73 | 1201 | 22 | 20 | 1469 |
| Hay, | 2268 | 247 | 84 | 914 | 705 | 118 | 1950 |
| Total, | 4536 | 517 | 188 | 2414 | 785 | 169 | 3904 |
| *Feces 5 Days.* | | | | | | | |
| Sheep B, | 1770 | 269 | 74 | 687 | 427 | 159 | 1457 |
| Sheep D, | 1382 | 196 | 51 | 576 | 317 | 124 | 1140 |
| *Amounts Digested.* | | | | | | | |
| Sheep B, | 2766 | 248 | 114 | 1727 | 358 | 10 | 2447 |
| Sheep D, | 3154 | 321 | 137 | 1838 | 468 | 45 | 2764 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep B, | — | 48.0 | 60.6 | 71.5 | 45.6 | 5.9 | 62.7 |
| Sheep D, | — | 62.1 | 72.9 | 76.1 | 59.6 | 26.6 | 70.8 |
| Average, | — | **55.1** | **66.8** | **73.8** | **52.6** | **16.3** | **66.8** |

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 2.

*Wheat bran, corn meal, linseed meal, oat and pea meal, and hay.*

Animals: as in Experiment No. 1. Experiment began February 5, 1894, and ended February 17, 1894. Feces collected for five days from February 12 at 3 P. M. to February 17 at 3 P. M. The amounts fed daily were as follows: Wheat bran, 4 ounces; corn meal, 1 ounce; linseed meal, 3 ounces; oat and pea meal, 8 ounces; hay, 1 pound. The experiment with both animals was apparently normal throughout. Tables 25 and 26, which follow, give the details of the experiment.

TABLE 25.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuffs.* | | % | % | % | % | % | % | % |
| Linseed mixture,* - | 1302 | 10.5 | 30.1 | 5.5 | 43.6 | 6.0 | 4.3 | 85.2 |
| Wheat bran,* - | 1304 | 8.8 | 18.1 | 5.1 | 52.0 | 10.2 | 5.8 | 85.4 |
| Oats and peas,* - | 1303 | 11.5 | 23.9 | 2.5 | 52.1 | 6.6 | 3.4 | 85.1 |
| Hay,* - - - | 1326 | 8.2 | 11.4 | 3.6 | 41.7 | 30.1 | 5.0 | 86.8 |
| *Feces.* | | | | | | | | |
| Sheep B, - - | 1309 | 7.6 | 14.9 | 4.2 | 38.2 | 24.4 | 10.7 | 81.7 |
| Sheep D, - - | 1310 | 7.4 | 16.7 | 3.5 | 37.6 | 24.0 | 10.8 | 81.8 |

* For analysis calculated to water-free substance, see pp. 23–25 of this Report.

TABLE 26.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | *Grams. | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Linseed mixture, - - | 567 | 171 | 31 | 247 | 34 | 24 | 483 |
| Wheat bran, - - - | 567 | 103 | 29 | 295 | 57 | 33 | 484 |
| Oats and peas, - - | 1134 | 271 | 28 | 591 | 75 | 39 | 965 |
| Hay, - - - - | 2268 | 258 | 82 | 946 | 683 | 113 | 1969 |
| Total, - - - | 4536 | 803 | 170 | 2079 | 849 | 209 | 3901 |
| *Feces 5 Days.* | | | | | | | |
| Sheep B, - - - | 1427 | 213 | 60 | 545 | 348 | 153 | 1166 |
| Sheep D, - - - | 1386 | 231 | 49 | 521 | 333 | 150 | 1134 |
| *Amounts Digested.* | | | | | | | |
| Sheep B, - - - | 3109 | 590 | 110 | 1534 | 501 | 56 | 2735 |
| Sheep D, - - - | 3150 | 572 | 121 | 1558 | 516 | 59 | 2767 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep B, - - - | — | 73.5 | 64.7 | 73.8 | 59.0 | 26.8 | 70.1 |
| Sheep D, - - - | — | 71.2 | 71.2 | 74.9 | 60.8 | 28.2 | 70.9 |
| Average, - - - | — | **72.3** | **67.9** | **74.3** | **59.9** | **27.5** | **70.5** |

* One pound contains 454 grams.

## DIGESTION EXPERIMENT NO. 3.

*Wheat bran, corn meal, linseed meal, oat and pea meal, and hay.*

The experiment was a duplicate of No. 2 with the animals and feed. The experiment began February 17, 1894, and ended March 1, 1894. Feces collected for five days from February 24 at 2:30 P. M. to March 1 at 2:30 P. M. The experiment was apparently normal throughout with both animals except that toward the close the feces of sheep B became quite soft, which may account for the larger weight of feces in the case of D and the consequent lower coefficient of digestion. Tables 27 and 28, which follow, give the details of the experiment.

TABLE 27.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuffs.* | | % | % | % | % | % | % | % |
| Linseed mixture,* - | 1339 | 11.1 | 29.4 | 5.5 | 43.7 | 6.1 | 4.2 | 84.7 |
| Wheat bran,* - | 1338 | 8.7 | 16.6 | 5.1 | 53.2 | 10.3 | 6.1 | 85.2 |
| Oats and peas,* - | 1340 | 11.4 | 22.2 | 2.5 | 52.9 | 7.7 | 3.3 | 85.3 |
| Hay,* - - - | 1327 | 8.5 | 11.1 | 3.6 | 39.2 | 32.3 | 5.3 | 86.2 |
| *Feces.* | | | | | | | | |
| Sheep B, - - | 1311 | 4.4 | 15.2 | 4.0 | 40.8 | 24.5 | 11.1 | 84.5 |
| Sheep D, - - | 1312 | 5.5 | 15.5 | 3.2 | 38.4 | 25.3 | 12.1 | 82.4 |

* For analysis calculated on water-free substance, see pp. 23–25 of this Report.

TABLE 28.

*Weights of Food Eaten and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | *Grams. | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Linseed mixture, - - | 567 | 167 | 31 | 248 | 34 | 24 | 480 |
| Wheat bran, - - - | 567 | 94 | 29 | 302 | 58 | 34 | 483 |
| Oats and peas, - - | 1134 | 252 | 28 | 600 | 87 | 37 | 967 |
| Hay, - - - - | 2268 | 252 | 81 | 889 | 733 | 120 | 1955 |
| Total, - - - | 4536 | 765 | 169 | 2039 | 912 | 215 | 3885 |
| *Feces 5 Days.* | | | | | | | |
| Sheep B, - - - | 1149 | 175 | 46 | 469 | 281 | 127 | 971 |
| Sheep D, - - - | 1402 | 217 | 45 | 538 | 355 | 170 | 1155 |
| *Amounts Digested.* | | | | | | | |
| Sheep B, - - - | 3387 | 590 | 123 | 1570 | 631 | 88 | 2914 |
| Sheep D, - - - | 3134 | 548 | 124 | 1501 | 557 | 45 | 2730 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep B, - - - | — | 77.1 | 72.8 | 77.0 | 69.2 | 40.9 | 75.0 |
| Sheep D, - - - | — | 71.6 | 73.4 | 73.6 | 61.1 | 20.9 | 70.3 |
| Average, - - - | — | **74.4** | **73.1** | **75.3** | **65.1** | **30.9** | **72.7** |

* One pound contains 454 grams.

## DIGESTION EXPERIMENT NO. 4.

*Wheat bran, corn meal and hay.*

This experiment is a duplicate of No. 1 with the same animals and feed. The experiment began March 3 and ended March 15, 1894. Feces collected for five days from March 10 at 9 A. M. to March 15 at 9 A. M. The experiment was apparently normal with both animals.

Tables 29 and 30, which follow, give the details of the experiment.

TABLE 29.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuffs.* | | % | % | % | % | % | % | % |
| Corn meal, - - | 1305 | 12.4 | 10.0 | 4.8 | 70.3 | 1.3 | 1.2 | 86.4 |
| Wheat bran, - - | 1306 | 8.7 | 16.8 | 5.2 | 54.1 | 9.4 | 5.8 | 85.5 |
| Hay, - - - | 1328 | 7.8 | 11.2 | 3.5 | 41.4 | 30.7 | 5.4 | 86.8 |
| *Feces.* | | | | | | | | |
| Sheep B, - - | 1313 | 8.1 | 17.0 | 4.6 | 37.6 | 23.5 | 9.2 | 82.7 |
| Sheep D, - - | 1314 | 8.4 | 17.2 | 3.8 | 37.8 | 24.0 | 8.8 | 82.8 |

TABLE 30.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | Grams * | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Corn meal, - - - | 1700 | 170 | 82 | 1195 | 22 | 20 | 1469 |
| Wheat bran, - - - | 568 | 95 | 30 | 307 | 53 | 33 | 485 |
| Hay, - - - - | 2268 | 254 | 79 | 939 | 696 | 122 | 1968 |
| Total, - - - | 4536 | 519 | 191 | 2441 | 771 | 175 | 3922 |
| *Feces for 5 Days.* | | | | | | | |
| Sheep B, - - - | 1292 | 220 | 59 | 486 | 303 | 119 | 1068 |
| Sheep D, - - - | 1441 | 248 | 55 | 544 | 346 | 127 | 1193 |
| *Amounts Digested.* | | | | | | | |
| Sheep B, - - - | 3244 | 299 | 132 | 1955 | 468 | 56 | 2854 |
| Sheep D, - - - | 3095 | 271 | 136 | 1897 | 425 | 48 | 2729 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep B, - - - | — | 57.6 | 69.1 | 80.1 | 60.7 | 32.0 | 72.8 |
| Sheep D, - - - | — | 52.2 | 71.2 | 77.7 | 55.2 | 27.4 | 69.6 |
| Average, - - - | — | **54.9** | **70.2** | **78.9** | **58.0** | **29.7** | **71.2** |

* One pound contains 454 grams.

## DIGESTION EXPERIMENT NO. 5.

*Scarlet clover fodder.*

Three animals, wethers, about one year old. Sheep, A, B and C were grade Shropshire dropped in the spring of 1893, and sheep B was grade Merino, also dropped in the spring of 1893. The experiment began May 26, 1894, and ended June 8, 1894. Feces collected for five days from June 3 at 8 A. M. to June 8 at 8 A. M. A and B were each fed ten pounds daily of the green scarlet clover and sheep D was fed eight pounds daily. The clover was cut at three different times, namely, May 26, May 28 and June 2. Each lot was sampled and analyzed by itself. At the time of taking the first sample, No. 1341, the clover was not quite in full bloom. Later, May 28, when sample 1342 was taken, the clover was in full bloom, and June 2, when the third sample was taken, the clover was a little past full bloom, the lower half of heads beginning to form the seed. The average of the last two cuttings, samples 1342 and 1343, were assumed to represent the average composition of the feed when used. The experiment with all three of the sheep was apparently normal throughout.

Tables 31 and 32, which follow, give the details of the experiment.

TABLE 31.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuff.* | | % | % | % | % | % | % | % |
| *Scarlet Clover,* Fed Green.* | | | | | | | | |
| Sample 1, - - | 1341 | 87.3 | 2.5 | .6 | 5.0 | 3.3 | 1.3 | 11.4 |
| Sample 2, - - | 1342 | 83.9 | 2.7 | .6 | 7.0 | 4.4 | 1.4 | 14.7 |
| Sample 3, - - | 1343 | 84.4 | 2.9 | .7 | 6.2 | 4.2 | 1.6 | 14.0 |
| Avg. of 1342 & 1343, | — | — | **2.8** | **.7** | **6.6** | **4.3** | **1.5** | **14.4** |
| *Feces.* | | | | | | | | |
| Sheep A, - - | 1344 | 7.1 | 11.6 | 4.1 | 30.0 | 35.2 | 12.0 | 80.9 |
| Sheep B, - - | 1345 | 7.4 | 11.6 | 4.8 | 30.6 | 33.4 | 12.2 | 80.4 |
| Sheep D, - - | 1346 | 9.0 | 11.4 | 3.9 | 30.6 | 33.7 | 11.4 | 79.6 |

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 32.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | Grams * | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Sheep A, - - - | 22680 | 635 | 159 | 1497 | 975 | 340 | 3266 |
| Sheep B, - - - | 22680 | 635 | 159 | 1497 | 975 | 340 | 3266 |
| Sheep D, - - - | 18140 | 508 | 127 | 1197 | 780 | 272 | 2612 |
| *Feces for 5 Days.* | | | | | | | |
| Sheep A, - - - | 1273 | 148 | 52 | 382 | 448 | 153 | 1030 |
| Sheep B, - - - | 1229 | 143 | 59 | 376 | 410 | 150 | 988 |
| Sheep D, - - - | 1014 | 116 | 39 | 310 | 342 | 116 | 807 |
| *Amounts Digested.* | | | | | | | |
| Sheep A, - - - | 21407 | 487 | 107 | 1115 | 527 | 187 | 2236 |
| Sheep B, - - - | 21451 | 492 | 100 | 1121 | 565 | 190 | 2278 |
| Sheep D, - - - | 17126 | 392 | 88 | 887 | 438 | 156 | 1805 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep A, - - - | — | 76.7 | 67.3 | 74.5 | 54.1 | 55.0 | 68.5 |
| Sheep B, - - - | — | 77.5 | 62.9 | 74.9 | 57.9 | 55.9 | 69.8 |
| Sheep D, - - - | — | 77.2 | 69.3 | 74.1 | 56.2 | 57.4 | 69.1 |
| Average, - - - | — | **77.1** | **66.5** | **74.5** | **56.1** | **56.1** | **69.1** |

* One pound contains 454 grams.

## DIGESTION EXPERIMENT NO. 6.

*Barley fodder.*

Two animals, A and D of experiment No. 5. Experiment began October 6, 1894, and ended October 18, 1894. Feces collected for five days from October 13 at noon to October 18 at noon. Each sheep was fed six pounds per day of the barley fodder. The barley was cut for feeding and samples were taken at four different times, namely, October 8, 11, 13, 15. At the time of taking the first sample, No. 1370, the barley was nearly grown and in full bloom. When the second sample was taken the barley was in bloom and beginning to seed. When the third sample, No. 1374, was taken, the barley was in early seeding and at the time of the last cutting it was still succulent. It was thought that it would be more nearly correct to use the average of the analyses of the second and third cuttings for the purpose of the experiment. With both animals the experiment was apparently normal throughout, except sheep A did not eat quite all the fodder which was fed.

Tables 33 and 34, which follow, give the details of the experiment.

TABLE 33.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuff.* | | % | % | % | % | % | % | % |
| *Barley Fodder,* Fed Green.* | | | | | | | | |
| Sample 1, - - | 1370 | 78.1 | 3.5 | .9 | 9.8 | 5.8 | 1.9 | 20.0 |
| Sample 2, - - | 1372 | 76.7 | 3.6 | .9 | 9.1 | 7.5 | 2.2 | 21.1 |
| Sample 3, - - | 1374 | 76.6 | 3.7 | .9 | 10.3 | 6.4 | 2.1 | 21.3 |
| Sample 4, - - | 1376 | 75.3 | 3.5 | .9 | 12.0 | 6.5 | 1.8 | 22.9 |
| Avg. of 1372 & 1374, | — | — | **3.6** | **.9** | **9.7** | **7.0** | **2.2** | **21.2** |
| *Feces.* | | | | | | | | |
| Sheep A, - - | 1383 | 6.8 | 11.2 | 3.5 | 30.4 | 36.7 | 11.4 | 81.8 |
| Sheep B, - - | 1384 | 6.2 | 13.7 | 4.4 | 30.6 | 34.0 | 11.1 | 82.7 |
| *Uneaten Residue.* | | | | | | | | |
| Sheep A, - - | 1409 | 8.2 | 16.5 | 4.3 | 39.4 | 23.8 | 7.8 | 84.0 |

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 34.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | Grams * | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Sheep B, - - - | 13610 | 490 | 122 | 1320 | 953 | 299 | 2885 |
| Sheep A, fed, - - - | 13463 | 466 | 116 | 1262 | 918 | 288 | 2762 |
| *Uneaten Residue.* | | | | | | | |
| Sheep A, - - - | 147 | 24 | 6 | 58 | 35 | 11 | 123 |
| *Feces for 5 Days.* | | | | | | | |
| Sheep A, - - - | 1275 | 143 | 45 | 387 | 468 | 145 | 1043 |
| Sheep B, - - - | 1022 | 140 | 45 | 313 | 347 | 113 | 845 |
| *Amounts Digested.* | | | | | | | |
| Sheep A, - - - | 12188 | 323 | 71 | 875 | 450 | 143 | 1719 |
| Sheep B, - - - | 12588 | 350 | 77 | 1007 | 606 | 186 | 2040 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep A, - - - | — | 69.3 | 61.2 | 69.3 | 49.0 | 49.7 | 62.2 |
| Sheep B, - - - | — | 71.4 | 63.1 | 76.3 | 63.6 | 62.2 | 70.7 |
| Average, - - - | — | **70.4** | **62.2** | **72.8** | **56.3** | **55.9** | **56.5** |

* One pound contains 454 grams.

DIGESTION EXPERIMENT NO. 7.

*Barley and pea fodder.*

Tables 35 and 36, which follow, give the details of the experiment. The description of the experiment follows the tables.

TABLE 35.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuffs.* | | % | % | % | % | % | % | % |
| *Barley & Pea Fodder,* Fed Green.* | | | | | | | | |
| Sample 1, - - | 1369 | 81.8 | 3.8 | .8 | 7.3 | 4.7 | 1.6 | 16.6 |
| Sample 2, - - | 1371 | 80.6 | 3.7 | .8 | 8.0 | 5.1 | 1.8 | 17.6 |
| Sample 3, - - | 1373 | 79.6 | 4.2 | 1.0 | 8.6 | 4.9 | 1.6 | 18.7 |
| Sample 4, - - | 1375 | 79.9 | 3.9 | .7 | 8.7 | 5.2 | 1.6 | 18.5 |
| Average of 1371 and 1373, - - - | — | — | **4.0** | **.9** | **8.3** | **5.0** | **1.7** | **18.2** |
| *Feces.* | | | | | | | | |
| Sheep C, - - | 1385 | 6.1 | 10.1 | 4.2 | 36.5 | 33.7 | 9.4 | 84.5 |
| Sheep D, - - | 1386 | 6.5 | 11.6 | 4.5 | 37.1 | 29.2 | 11.1 | 82.4 |
| *Uneaten Residue.* | | | | | | | | |
| Sheep D, - - | 1417 | 6.5 | 11.9 | 2.2 | 38.4 | 32.1 | 8.9 | 84.6 |

* For analysis calculated on water-free substance, see pp. 23–25 of this Report.

TABLE 36.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | Grams* | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Sheep C, - - - | 13610 | 544 | 122 | 1130 | 681 | 231 | 2477 |
| Sheep D, fed, - - | 13136 | 488 | 112 | 948 | 529 | 189 | 2077 |
| *Uneaten Residue.* | | | | | | | |
| Sheep D, - - - | 474 | 56 | 10 | 182 | 152 | 42 | 400 |
| *Feces for 5 Days.* | | | | | | | |
| Sheep C, - - - | 1022 | 103 | 43 | 373 | 345 | 96 | 864 |
| Sheep D, - - - | 1130 | 131 | 51 | 419 | 330 | 125 | 931 |
| *Amounts Digested.* | | | | | | | |
| Sheep C, - - - | 12588 | 441 | 79 | 757 | 336 | 135 | 1613 |
| Sheep D, - - - | 12006 | 357 | 61 | 529 | 199 | 64 | 1146 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep C, - - - | — | 81.1 | 64.8 | 67.0 | 49.3 | 58.4 | 65.1 |
| Sheep D, - - - | — | 73.2 | 54.5 | 55.8 | 37.6 | 33.9 | 55.2 |
| Average, - - - | — | **77.2** | **59.7** | **61.4** | **43.5** | **46.2** | **60.2** |

* One pound contains 454 grams.

Two animals, B and C, of digestion experiment No. 5. Experiment began October 6, 1894, and ended October 18, 1894. Feces collected for five days from October 13, noon, to October 18, noon. Each sheep was fed daily six pounds of the green fodder. The fodder was cut at four different times, October 8,

11, 13 and 15. At the time of the first cutting, sample 1369, the barley was nearly grown and in early bloom; the peas were beginning to bloom. At the time of the second cutting, sample 1371, the barley was nearly grown, in bloom and beginning to seed. The peas had blossoms. At the time of the third cutting, sample 1373, the barley was in early seeding and the peas in full bloom; and at the time of the last cutting, sample 1375, the barley was in early seeding and still succulent, peas mostly still green and in bloom. The average of the analyses of the second and third cuttings were assumed to represent the composition of the food experimented upon. With both animals the experiment was apparently normal throughout, except that sheep D did not eat up all of the fodder which was given it.

### DIGESTION EXPERIMENT NO. 8.

*Rowen hay from mixed grasses.*

Four animals, wethers, the same as used in experiments 5, 6, and 7. Experiment began November 16 and ended November 28, 1894. Feces of C and D were collected for four and one-half days, from November 24 at 6 A. M. to November 28 at 4:30 P. M. The feces of sheep C and D were collected for five days, from November 23 at 4:30 P. M. to November 28 at 4:30 P. M. Each animal was fed two pounds of the rowen daily. The rowen was from mixed grasses, chiefly Kentucky blue grass and a little orchard grass and meadow fescue. It was grown by the Station in 1894 and harvested about September 25. With all four sheep the experiment was apparently normal throughout.

Tables 37 and 38, which follow, give the details of the experiment.

TABLE 37.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuff.* | | % | % | % | % | % | % | % |
| Rowen hay,* from mixed grasses, - | 1400 | 14.8 | 14.6 | 4.5 | 35.6 | 24.1 | 6.4 | 78.8 |
| *Feces.* | | | | | | | | |
| Sheep A, - - | 1395 | 5.6 | 14.1 | 7.2 | 37.2 | 26.4 | 9.4 | 84.9 |
| Sheep B, - - | 1396 | 6.2 | 13.9 | 7.4 | 38.6 | 24.4 | 9.5 | 84.3 |
| Sheep C, - - | 1397 | 5.9 | 13.1 | 7.4 | 40.3 | 24.7 | 8.6 | 85.5 |
| Sheep D, - - | 1398 | 5.9 | 14.7 | 7.9 | 37.4 | 24.4 | 9.7 | 84.4 |

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 38.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N. × 6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 4½ Days.* | Grams * | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Sheep A, - - - - | 4080 | 596 | 184 | 1452 | 983 | 261 | 3215 |
| Sheep B, - - - - | 4080 | 596 | 184 | 1452 | 983 | 261 | 3215 |
| *Eaten in 5 Days.* | | | | | | | |
| Sheep C, - - - - | 4535 | 661 | 204 | 1613 | 1092 | 290 | 3570 |
| Sheep D, - - - - | 4535 | 661 | 204 | 1613 | 1092 | 290 | 3570 |
| *Feces for 4½ Days.* | | | | | | | |
| Sheep A, - - - - | 1260 | 178 | 91 | 469 | 332 | 118 | 1070 |
| Sheep B, - - - - | 1393 | 193 | 103 | 538 | 340 | 132 | 1174 |
| *Feces for 5 Days.* | | | | | | | |
| Sheep C, - - - - | 1500 | 197 | 111 | 604 | 370 | 129 | 1282 |
| Sheep D, - - - - | 1424 | 209 | 113 | 533 | 347 | 138 | 1202 |
| *Amounts Digested.* | | | | | | | |
| Sheep A, - - - - | 2820 | 418 | 93 | 983 | 651 | 143 | 2145 |
| Sheep B, - - - - | 2687 | 403 | 81 | 914 | 643 | 129 | 2041 |
| Sheep C, - - - - | 3035 | 464 | 93 | 1009 | 722 | 161 | 2288 |
| Sheep D, - - - - | 3111 | 452 | 91 | 1080 | 745 | 152 | 2368 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep A, - - - - | — | 70.1 | 50.5 | 67.7 | 66.2 | 54.8 | 66.7 |
| Sheep B, - - - - | — | 67.6 | 44.0 | 62.9 | 65.4 | 49.4 | 63.5 |
| Sheep C, - - - - | — | 70.2 | 45.6 | 62.6 | 66.1 | 55.5 | 64.1 |
| Sheep D, - - - - | — | 68.4 | 44.6 | 67.0 | 68.2 | 52.4 | 66.3 |
| Average, - - - - | — | **69.1** | **46.2** | **65.1** | **66.5** | **53.0** | **65.2** |

* One pound contains 454 grams.

## DIGESTION EXPERIMENT NO. 9.

*Rowen hay, mostly timothy.*

The same animals were used as in experiments 5 to 8. The experiment was begun December 3, 1894, and ended December 15, 1894. Feces were collected for five days, from December 10 at 5 P. M. to December 15 at 5 P. M. Each sheep received daily two pounds of the rowen. The rowen consisted chiefly of timothy with a little barn grass. With all four sheep the experiment was apparently normal throughout, except that sheep D left some uneaten portions of that which was fed to it. Tables 39 and 40, which follow, give the details of the experiment.

TABLE 39.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuff.* | | % | % | % | % | % | % | % |
| Rowen hay,* mostly timothy, - - | 1399 | 18.6 | 13.2 | 4.3 | 32.5 | 24.8 | 6.6 | 74.8 |
| *Feces.* | | | | | | | | |
| Sheep A, - - | 1401 | 8.0 | 13.8 | 6.5 | 35.1 | 26.6 | 10.0 | 82.0 |
| Sheep B, - - | 1402 | 7.0 | 12.5 | 6.9 | 39.3 | 29.1 | 5.2 | 87.8 |
| Sheep C, - - | 1403 | 7.8 | 12.9 | 6.8 | 36.5 | 26.5 | 9.5 | 82.7 |
| Sheep D, - - | 1404 | 8.0 | 14.1 | 7.3 | 37.2 | 21.9 | 11.5 | 80.5 |
| *Uneaten Residue.* | | | | | | | | |
| Sheep D, - - | 1410 | 6.4 | 10.4 | 2.6 | 48.0 | 25.0 | 7.6 | 86.0 |

* For analysis calculated on water-free substance, see pp. 23-25 of this Report.

TABLE 40.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | Grams* | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Sheep A, - - - - | 4535 | 598 | 195 | 1474 | 1125 | 299 | 3392 |
| Sheep B, - - - - | 4535 | 598 | 195 | 1474 | 1125 | 299 | 3392 |
| Sheep C, - - - - | 4535 | 598 | 195 | 1474 | 1125 | 299 | 3392 |
| Sheep D, fed, - - | 4216 | 565 | 187 | 1321 | 1045 | 275 | 3118 |
| *Uneaten Residue.* | | | | | | | |
| Sheep D, - - - - | 319 | 33 | 8 | 153 | 80 | 24 | 274 |
| *Feces for 5 Days.* | | | | | | | |
| Sheep A, - - - - | 1473 | 203 | 96 | 517 | 392 | 147 | 1208 |
| Sheep B, - - - - | 1467 | 183 | 101 | 577 | 427 | 76 | 1288 |
| Sheep C, - - - - | 1474 | 190 | 100 | 538 | 391 | 140 | 1219 |
| Sheep D, - - - - | 1270 | 179 | 93 | 472 | 278 | 146 | 1022 |
| *Amounts Digested.* | | | | | | | |
| Sheep A, - - - - | 3062 | 395 | 99 | 957 | 733 | 152 | 2184 |
| Sheep B, - - - - | 3068 | 415 | 94 | 897 | 698 | 223 | 2104 |
| Sheep C, - - - - | 3061 | 408 | 95 | 936 | 734 | 159 | 2173 |
| Sheep D, - - - - | 2946 | 386 | 94 | 849 | 767 | 129 | 2096 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep A, - - - - | — | 66.1 | 50.8 | 64.9 | 65.2 | 50.8 | 64.4 |
| Sheep B, - - - - | — | 69.4 | 48.2 | 60.9 | 62.0 | 74.6 | 62.0 |
| Sheep C, - - - - | — | 68.2 | 48.7 | 63.5 | 65.2 | 53.2 | 64.1 |
| Sheep D, - - - - | — | 68.3 | 50.3 | 64.3 | 73.4 | 46.9 | 67.2 |
| Average, - - - | — | **68.0** | **49.5** | **63.4** | **66.5** | **56.4** | **64.4** |

* One pound contains 454 grams.

## DIGESTION EXPERIMENT NO. 10.

*Scarlet clover hay, field cured.*

The animals were the same as in experiments 5 to 9. The experiment began December 26, 1894, and ended January 7, 1895.

Feces were collected for five days from January 2, 5 P. M., to January 7, 5 P. M. Each sheep was fed daily one and one-half pounds of the rowen. The scarlet clover hay was cut June 4, 1894, and dried in cocks. At time of cutting it was a little past full bloom, many of the heads beginning to seed at the base. The experiment was apparently normal with all four animals. They all ate up the feed completely and seemed to be hungry. Tables 41 and 42, which follow, give the details of the experiment.

TABLE 41.

*Composition of Feeding Stuffs and Feces.*

| KIND OF MATERIAL. | Lab'ty No. | Water. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| *Feeding Stuff.* | | % | % | % | % | % | % | % |
| Scarlet clover* hay, | 1418 | 13.9 | 14.1 | 1.8 | 31.6 | 31.3 | 7.3 | 78.8 |
| *Feces.* | | | | | | | | |
| Sheep A, - - | 1419 | 5.4 | 10.5 | 2.1 | 29.7 | 43.6 | 8.7 | 85.9 |
| Sheep B, - - | 1420 | 6.9 | 10.6 | 2.1 | 27.6 | 42.8 | 10.0 | 83.1 |
| Sheep C, - - | 1421 | 6.3 | 10.4 | 2.3 | 32.0 | 39.8 | 9.2 | 84.5 |
| Sheep D, - - | 1422 | 5.5 | 11.1 | 2.1 | 31.1 | 41.3 | 8.9 | 85.6 |

* For analysis calculated on water-free substance, see pp. 23–25 of this Report.

TABLE 42.

*Weights of Food Eaten, and of Feces for Five Days, and Weights and Percentages of Nutrients Digested.*

| | Weight. | Protein. N.×6.25. | Fat. | Nit.-free Ext | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|
| *Eaten in 5 Days.* | Grams* | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Sheep A, - - - - | 3300 | 427 | 55 | 958 | 948 | 221 | 2388 |
| Sheep B, - - - - | 3300 | 427 | 55 | 958 | 948 | 221 | 2388 |
| Sheep C, - - - - | 3300 | 427 | 55 | 958 | 948 | 221 | 2388 |
| Sheep D, - - - - | 3300 | 427 | 55 | 958 | 948 | 221 | 2388 |
| *Feces for Five Days.* | | | | | | | |
| Sheep A, - - - - | 1469 | 154 | 31 | 436 | 641 | 128 | 1262 |
| Sheep B, - - - - | 1455 | 154 | 31 | 401 | 623 | 145 | 1209 |
| Sheep C, - - - - | 1433 | 149 | 33 | 459 | 570 | 132 | 1211 |
| Sheep D, - - - - | 1359 | 151 | 29 | 422 | 561 | 121 | 1163 |
| *Amounts Digested.* | | | | | | | |
| Sheep A, - - - - | 1831 | 273 | 24 | 522 | 307 | 93 | 1126 |
| Sheep B, - - - - | 1845 | 273 | 24 | 557 | 325 | 76 | 1179 |
| Sheep C, - - - - | 1867 | 278 | 22 | 499 | 378 | 89 | 1177 |
| Sheep D, - - - - | 1941 | 276 | 26 | 536 | 387 | 100 | 1225 |
| *Per Cent. Digested.* | | % | % | % | % | % | % |
| Sheep A, - - - - | — | 63.9 | 43.6 | 54.5 | 32.4 | 42.1 | 47.2 |
| Sheep B, - - - - | — | 63.9 | 43.6 | 58.1 | 34.3 | 34.4 | 49.4 |
| Sheep C, - - - - | — | 65.1 | 40.0 | 52.1 | 39.9 | 40.3 | 49.3 |
| Sheep D, - - - - | — | 64.6 | 47.3 | 55.9 | 40.8 | 45.3 | 51.3 |
| Average, - - - | — | **65.4** | **43.6** | **55.2** | **36.9** | **40.5** | **49.3** |

* One pound contains 454 grams.

TABLE 43.

*Summary of Results of Digestion Experiments with Sheep Herewith Reported Upon—Percentages of Total Nutrients of Food Actually Digested.*

| Kind of Food. | Current No. of Experiment. | Sheep. | Protein. N. × 6.25. | Fat. | Nitrogen-free Extract. | Fiber. | Ash. | Organic Matter. |
|---|---|---|---|---|---|---|---|---|
| | | | % | % | % | % | % | % |
| Wheat bran 4 oz., corn meal 12 oz., and hay 1 lb. The wide ration of sheep feeding experiment, pp. 92-106, this Report. | 1 | B, | 48.0 | 60.6 | 71.5 | 45.6 | 5.9 | 62.7 |
| | 1 | D, | 62.1 | 72.9 | 76.1 | 59.6 | 26.6 | 70.8 |
| | 4 | B, | 57.6 | 69.1 | 80.1 | 60.7 | 32.0 | 72.8 |
| | 4 | D, | 52.2 | 71.2 | 77.7 | 55.2 | 27.4 | 69.6 |
| Avg. 2 experiments and 4 tests, | — | — | **55.0** | **68.5** | **76.4** | **55.3** | **23.0** | **69.0** |
| Wheat bran 4 oz., corn meal 1 oz., linseed meal 3 oz., oat and pea meal 8 oz., hay 1 lb. The narrow ration of sheep feeding experiment, pp. 92–106, this Report. | 2 | B, | 73.5 | 64.7 | 73.8 | 59.0 | 26.8 | 70.1 |
| | 2 | D, | 71.2 | 71.2 | 74.9 | 60.8 | 28.2 | 70.9 |
| | 3 | B, | 77.1 | 72.8 | 77.0 | 69.2 | 40.9 | 75.0 |
| | 3 | D, | 71.6 | 73.4 | 73.6 | 61.1 | 20.9 | 70.3 |
| Avg. 2 experiments and 4 tests, | — | — | **73.4** | **70.5** | **74.8** | **62.5** | **29.2** | **71.6** |
| Scarlet clover fodder, fed green, - - - - | 5 | A, | 76.7 | 67.3 | 74.5 | 54.1 | 55.0 | 68.5 |
| | 5 | B, | 77.5 | 62.9 | 74.9 | 57.9 | 55.9 | 69.8 |
| | 5 | D, | 77.2 | 69.3 | 74.1 | 56.2 | 57.4 | 69.1 |
| Avg. 1 experiment and 3 tests, | — | — | **77.1** | **66.5** | **74.5** | **56.1** | **56.1** | **69.1** |
| Scarlet clover hay, - - | 10 | A, | 63.9 | 43.6 | 54.5 | 32.4 | 42.1 | 47.2 |
| | 10 | B, | 63.9 | 43.6 | 58.1 | 34.3 | 34.4 | 49.4 |
| | 10 | C, | 65.1 | 40.0 | 52.1 | 39.9 | 40.3 | 49.3 |
| | 10 | D, | 64.6 | 47.3 | 55.9 | 40.8 | 45.3 | 51.3 |
| Avg. 1 experiment and 4 tests, | — | — | **65.4** | **43.6** | **55.2** | **36.9** | **40.5** | **49.3** |
| Barley fodder, fed green, - | 6 | A, | 69.3 | 61.2 | 69.3 | 49.0 | 49.7 | 62.2 |
| | 6 | B, | 71.4 | 63.1 | 76.3 | 63.6 | 62.2 | 70.7 |
| Avg. 1 experiment and 2 tests, | — | — | **70.4** | **62.2** | **72.8** | **56.3** | **55.9** | **56.5** |
| Barley and pea fodder, - - | 7 | C, | 81.1 | 64.8 | 67.0 | 49.3 | 58.4 | 65.1 |
| | 7 | D, | 73.2 | 54.5 | 55.8 | 37.6 | 33.9 | 55.2 |
| Avg. 1 experiment and 2 tests, | — | — | **77.2** | **59.7** | **61.4** | **43.5** | **46.2** | **60.2** |
| Rowen hay, mixed grasses, chiefly Kentucky blue grass, | 8 | A, | 70.1 | 50.5 | 67.7 | 66.2 | 54.8 | 66.7 |
| | 8 | B, | 67.6 | 44.0 | 62.9 | 65.4 | 49.4 | 63.5 |
| | 8 | C, | 70.2 | 45.6 | 62.6 | 66.1 | 55.5 | 64.1 |
| | 8 | D, | 68.4 | 44.6 | 67.0 | 68.2 | 52.4 | 66.3 |
| Avg. 1 experiment and 4 tests, | — | — | **69.1** | **46.2** | **65.1** | **66.5** | **53.0** | **65.2** |
| Rowen hay, mostly timothy, | 9 | A, | 66.1 | 50.8 | 64.9 | 65.2 | 50.8 | 64.4 |
| | 9 | B, | 69.4 | 48.2 | 60.9 | 62.0 | 74.6 | 62.0 |
| | 9 | C, | 68.2 | 48.7 | 63.5 | 65.2 | 53.2 | 64.1 |
| | 9 | D, | 68.3 | 50.3 | 64.3 | 73.4 | 46.9 | 67.2 |
| Avg. 1 experiment and 4 tests, | — | — | **68.0** | **49.5** | **63.4** | **66.5** | **56.4** | **64.4** |

# FUEL VALUES OF DIGESTED NUTRIENTS IN EXPERIMENTS IN SHEEP.

BY W. O. ATWATER AND CHAS. D. WOODS.

In connection with the digestion experiments with sheep described in the preceding paper (pp. 107-122), the heats of combustion of the feeding stuffs and feces were determined by use of the bomb calorimeter, with the purpose of getting light upon the potential energy or fuel value of the digested material.*

The problem is, however, not as simple as these brief statements imply. Indeed it is extremely complex, but for the present purpose it will suffice to say that while most of the unconsumed material of the food leaves the body in the undigested food residue of the feces, a small portion escapes in urea and other substances of the urine. These last substances come from the digested material of the food; they are digested material which has not been completely consumed, and they contain potential energy. If, therefore, we are to find how much of the potential energy of the food has been set free in the body we must subtract from the total energy of the food, the sum of the amounts excreted in both feces and urine. The remainder is taken as the measure of the actual fuel value of the food.

Food has two chief uses. The first is to build up the materials of the body and repair their wastes, the second is to yield energy in the form of heat to keep it warm and strength for its work. The nutritive ingredients or nutrients of the food make blood and muscle, bone and milk and other tissues and fluids of the body and replace them as they are used up. But only the portions which are actually digested serve these purposes. Hence to learn the nutritive value of food we endeavor to find how much of each of its nutrients is digested and thus made useful for building and repair. To do this we learn how much of

* The bomb calorimeter is described in a succeeding article, page 135. Brief explanations of potential energy and fuel values are given on pages 43 and 44.

nutrients was contained in the food eaten and how much was left in the undigested residue. The difference is taken as the measure of the amount digested. In the same way, it is the potential energy of the digested material which is made available to the body in the forms of heat and muscular power. The energy of the undigested material is lost to the body. To learn how much of the energy of the food is available we must find how much potential energy was contained in the food eaten and how much is left in the residues not used in the body. The difference will be the amount set free and made available for fuel.

The potential energy of the food and the unconsumed residues is learned by burning the materials in the calorimeter and measuring the heat produced. This method has been followed in connection with the digestion experiments referred to.

The experiments here described are, so far as the writers know, the first attempt in this direction.* The results are far from being all that could be desired. We have not yet found a perfectly satisfactory method for determination of the heat of combustion of the solid matters of the urine, though we hope for better success in due time. A number of collateral subjects call for study, some of which are already entered upon. The purpose here is simply to report some of the first results obtained.

The much needed study of the general subject requires the taking into account of the total income and outgo of the body as expressed in terms of matter and of energy. This is the purpose of the respiration calorimeter which is now being elaborated by coöperation of the Station in the chemical laboratory of Wesleyan University, to which reference was made in the last Annual Report of this Station.†

The purpose of the present article is to record some of the observations already made. An explanation of the way in which the principal data are obtained is given with the details of the latter in the case of experiment No. 1. For the other experiments only the data are cited. The results of all the experiments are summarized in table 44.

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* Prof. H. P. Armsby, of the Pennsylvania Experiment Station, has conducted a series of feeding experiments in which the heats of combustion of food and residues were determined by one of us with the calorimeter used in the experiments here described, but the results are not yet published.

† Report for 1893, page 16.

## DIGESTION EXPERIMENT NO. I.

(See page 109, this Report.)

*Bran, corn meal and hay.*

In this experiment three different feeding stuffs were employed. The composition of each was determined by analyses. Their fuel values were determined by combustion in the bomb calorimeter, and were also calculated from the chemical composition. The methods employed for calculating from chemical composition are those explained in the Report of this Station for 1890, pages 174–181, and are also referred to on page 43 of this Report. The fuel values as obtained in the two ways were somewhat different, as appears from the following figures:

*Fuel Values—Calories per Gram of Water-free Substance.*

| | Laboratory No. | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|---|
| Bran, | 1301 | 4.430 | 4.585 |
| Corn meal, | 1300 | 4.460 | 4.520 |
| Hay, | 1325 | 4.245 | 4.515 |

The fuel value of the total food eaten in five days was obtained by multiplying the number of grams of food by the fuel value per gram as determined by the bomb calorimeter.

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

| | | |
|---|---|---|
| Fuel value of bran, | 2,360 | Calories. |
| Fuel value of corn meal, | 6,725 | Calories. |
| Fuel value of hay, | 9,345 | Calories. |
| Total fuel value of food eaten, | 18,430 | Calories. |

The feces were burned in the bomb calorimeter. Multiplying the number of grams by the fuel value of one gram gives the figures which follow:

| | | |
|---|---|---|
| Sheep B, | 7,600 | Calories. |
| Sheep D, | 5,920 | Calories. |

When protein is burned in the calorimeter it is completely oxidized, the carbon being burned to carbon dioxide and the hydrogen to water. The nitrogen is left uncombined. When protein is consumed in the body the oxidation is not complete. The nitrogen is left in urea, uric acid and other allied compounds, all of which contain carbon and hydrogen, together with some oxygen. In estimating the actual fuel value of the digested ingredients which an animal can utilize, allowance must be made for these unconsumed residual products, which are excreted by the kidneys. Urea is usually the most abundant of these excretory products, and it is here assumed that all of the nitrogen of the digested protein is excreted as urea. The fuel value of urea as determined by Stohmann and Berthelot is 2.53 Calories per gram.*

The method used in the calculations here has been as follows: Urea ($CON_2H_4$) contains 46.67 per cent. of nitrogen. Hence nitrogen multiplied by the factor 2.143 equals urea. The protein as here estimated is the nitrogen

* See Bulletin No. 21 of the Office of Experiment Stations, U. S. Department of Agriculture, on Methods and Results of Investigations of the Chemistry and Economy of Food, for a more detailed discussion of the subject.

multiplied by 6.25. Hence dividing the protein by 6.25 and multiplying the quotient by 2.143 gives the equivalent urea. Assuming that all of the digested protein is excreted as urea, the number of grams of urea multiplied by 2.53, the fuel value of one gram of urea, gives the total fuel value of the urea equivalent to the digested protein. But (protein divided by 6.25) $\times$ 2.143 $\times$ 2.53 = protein $\times$ .87. This last expression, protein $\times$ .87, therefore, represents the fuel value of the urea equivalent to the digestible protein. The fuel values of urea equivalent to the protein in this experiment and the total unused fuel value (the sum of the fuel values of the feces and of the urea equivalent to the protein) are as follows:

*Fuel Values of Urea Equivalent to Digested Protein.*

Sheep B, - - - - - - - - - 215 Calories.
Sheep D, - - - - - - - - - 280 Calories.

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

Sheep B, - - - - - - - - - 7,815 Calories.
Sheep D, - - - - - - - - - 6,200 Calories.

The available fuel value of the digested nutrients is the difference between the fuel value of the total food eaten and the total unused fuel value. Omitting details of calculations the results follow. With these results are given for the sake of comparison those obtained by taking the grams of nutrients digested as stated on page 110, and multiplying the protein by 5.5, the carbohydrates by 4.1 and the fats by 9.3 Calories.

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep B, - - - - - - | 10,625 Calories. | 10,615 Calories. |
| Sheep D, - - - - - - | 12,050 Calories. | 12,230 Calories. |

Dividing the fuel value of the digested nutrients by the fuel value of the food eaten gives the per cent. of total fuel value which thus becomes available. These percentages follow. With them are the percentages of digestible protein, taken from the Report of this experiment on page 110.

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep B, 48.0 per cent. of total protein and 57.6 per cent. of total fuel value.
Sheep D, 62.1 per cent. of total protein and 66.4 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 2.

(See page 111, this Report.)

*Wheat bran, corn meal, linseed meal, oat and pea meal, and hay.*

*Calories per Gram of Water-free Substance.*

| | Laboratory No. | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|---|
| Wheat bran, - - - | 1304 | 4.405 | 4.585 |
| Linseed meal, - - - | 1302 | 4.690 | 4.735 |
| Oat and pea meal, - - | 1303 | 4.470 | 4.530 |
| Hay, - - - - | 1426 | 4.255 | 4.505 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

| | |
|---|---|
| Fuel value of bran, | 2,370 Calories. |
| Fuel value of linseed meal and corn meal, | 2,465 Calories. |
| Fuel value of oat and pea meal, | 4,540 Calories. |
| Fuel value of hay, | 9,375 Calories. |
| Total fuel value of food eaten, | 18,750 Calories. |

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

| | |
|---|---|
| Sheep B, | 6,150 Calories. |
| Sheep D, | 5,940 Calories. |

*Fuel Value of Urea Equivalent to Digested Protein.*

| | |
|---|---|
| Sheep B, | 680 Calories. |
| Sheep D, | 655 Calories. |

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

| | |
|---|---|
| Sheep B, | 6,830 Calories. |
| Sheep D, | 6,595 Calories. |

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep B, | 11,785 Calories. | 11,920 Calories. |
| Sheep D, | 11,975 Calories. | 12,155 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep B, 73.5 per cent. of total protein and 63.6 per cent. of total fuel value.
Sheep D, 71.2 per cent. of total protein and 64.8 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 3.

(See page 112, this Report.)

*Wheat bran, corn meal, linseed meal, oat and pea meal, and hay.*

*Calories per Gram of Water-free Substance.*

| | Laboratory No. | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|---|
| Wheat bran, | 1338 | 4.376 | 4.530 |
| Linseed meal and corn meal, | 1339 | 4.685 | 4.750 |
| Oat and pea meal, | 1340 | 4.445 | 4.515 |
| Hay, | 1327 | 4.235 | 4.520 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

| | |
|---|---|
| Wheat bran, | 2,345 Calories. |
| Linseed meal and corn meal, | 2,395 Calories. |
| Oat and pea meal, | 4,535 Calories. |
| Hay, | 9,380 Calories. |
| Total fuel value of food eaten, | 18,655 Calories. |

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

Sheep B, - - - - - - - - - - 5,030 Calories.
Sheep D, - - - - - - - - - - 5,980 Calories.

*Fuel Value of Urea Equivalent to Digested Protein.*

Sheep B, - - - - - - - - - - 505 Calories.
Sheep D, - - - - - - - - - - 475 Calories.

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

Sheep B, - - - - - - - - - 5,535 Calories.
Sheep D, - - - - - - - - - - 6,455 Calories.

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep B, - - - - - - | 12,585 Calories. | 13,120 Calories. |
| Sheep D, - - - - - - | 11,850 Calories. | 12,200 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep B, 77.1 per cent. of total protein and 70.3 per cent. of total fuel value.
Sheep D, 71.6 per cent. of total protein and 65.4 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 4.

(See page 113, this Report.)

*Bran, corn meal and hay.*

*Calories per Gram Water-free Substance.*

| | Laboratory No. | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|---|
| Bran, - - - - | 1306 | 4.395 | 4.555 |
| Corn meal, - - - | 1305 | 4.485 | 4.505 |
| Hay, - - - - - | 1328 | 4.230 | 4.505 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

Fuel value of bran, - - - - - - - - - 2,365 Calories.
Fuel value of corn meal, - - - - - - - 6,705 Calories.
Fuel value of hay, - - - - - - - - - 9,410 Calories.

Total fuel value of food eaten, - - - - - - 18,480 Calories.

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

Sheep B, - - - - - - - - - - 5,680 Calories.
Sheep D, - - - - - - - - - - 6,245 Calories.

*Fuel Value of Urea Equivalent to Digested Protein.*

Sheep B, - - - - - - - - - - 260 Calories.
Sheep D, - - - - - - - - - - 190 Calories.

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

Sheep B, - - - - - - - - - - 5,940 Calories.
Sheep D, - - - - - - - - - - 6,435 Calories.

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep B, - - - - - - | 12,540 Calories. | 12,390 Calories. |
| Sheep D, - - - - - - | 12,045 Calories. | 11,895 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep B, 57.6 per cent. of total protein and 67.9 per cent. of total fuel value.

Sheep D, 52.2 per cent. of total protein and 65.2 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 5.

(See page 114, this Report.)

*Scarlet fodder, fed green.*

*Calories per Gram of Water-free Substance.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Scarlet clover, average, - - - | 4.190 | 4.390 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

Sheep A and B, - - - - - - - - - 15,875 Calories.

Sheep D, - - - - - - - - - - 12,700 Calories.

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

Sheep A, - - - - - - - - - - 5,340 Calories.

Sheep B, - - - - - - - - - - 5,240 Calories.

Sheep D, - - - - - - - - - - 4,200 Calories.

*Fuel Value of Urea Equivalent to Digested Protein.*

Sheep A, - - - - - - - - - - 425 Calories.

Sheep B, - - - - - - - - - - 430 Calories.

Sheep D, - - - - - - - - - - 340 Calories.

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

Sheep A, - - - - - - - - - - 5,765 Calories.

Sheep B, - - - - - - - - - - 5,670 Calories.

Sheep D, - - - - - - - - - - 4,540 Calories.

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep A, - - - - - - | 9,730 Calories. | 10,110 Calories. |
| Sheep B, - - - - - - | 9,860 Calories. | 10,205 Calories. |
| Sheep D, - - - - - - | 7,860 Calories. | 8,160 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep A, 76.7 per cent. of total protein and 63.7 per cent. of total fuel value.

Sheep B, 77.5 per cent. of total protein and 64.3 per cent. of total fuel value.

Sheep D, 77.2 per cent. of total protein and 64.3 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 6.

(See page 115, this Report).

*Barley fodder fed green.*

*Calories per Gram of Water-free Substance.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Barley fodder, average, - - - - | 4.135 | 4.520 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

Sheep A, - - - - - - - - - - 13,735 Calories.
Sheep B, - - - - - - - - - - 14,360 Calories.

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

Sheep A, - - - - - - - - - - 5,520 Calories.
Sheep B, - - - - - - - - - - 4,515 Calories.

*Fuel Value of Urea Equivalent to Digested Protein.*

Sheep A, - - - - - - - - - - 280 Calories.
Sheep B, - - - - - - - - - - 305 Calories.

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

Sheep A, - - - - - - - - - - 5,800 Calories.
Sheep B, - - - - - - - - - - 4,820 Calories.

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep A, - - - - - - | 7,415 Calories. | 7,935 Calories. |
| Sheep B, - - - - - - | 8,765 Calories. | 9,540 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep A, 69.3 per cent. of total protein and 57.8 per cent. of total fuel value.
Sheep B, 71.4 per cent. of total protein and 66.4 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 7.

(See page 116, this Report.)

*Barley and pea fodder, fed green.*

*Calories per Gram of Water-free Substance.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Barley and pea fodder, average, - - | 4.255 | 4.570 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

Sheep C, - - - - - - - - - - 12,385 Calories.
Sheep D, - - - - - - - - - - 10,435 Calories.

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

Sheep C, - - - - - - - - - - 4,540 Calories.
Sheep D, - - - - - - - - - - 4,975 Calories.

*Fuel Value of Urea Equivalent to Digested Protein.*

| | |
|---|---|
| Sheep C, - - - - - - - - - - | 385 Calories. |
| Sheep D, - - - - - - - - - - | 310 Calories. |

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

| | |
|---|---|
| Sheep C, - - - - - - - - - - | 4,925 Calories. |
| Sheep D, - - - - - - - - - - | 5,285 Calories. |

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep C, - - - - - - | 7,025 Calories. | 7,460 Calories. |
| Sheep D, - - - - - - | 5,055 Calories. | 5,150 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep C, 81.1 per cent. of total protein and 60.2 per cent. of total fuel value.
Sheep D, 73.2 per cent. of total protein and 49.4 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 8.

(See page 118, this Report.)

*Rowen hay, from mixed grasses.*

*Calories per Gram of Water-free Substance.*

| | Laboratory No. | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|---|
| Rowen, - - - - | 1400 | 4.310 | 4.675 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

| | |
|---|---|
| Sheep A and B, each, - - - - - - - - | 16,265 Calories. |
| Sheep C and D, each, - - - - - - - - | 18,060 Calories. |

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

| | |
|---|---|
| Sheep A, - - - - - - - - - - | 5,995 Calories. |
| Sheep B, - - - - - - - - - - | 6,620 Calories. |
| Sheep C, - - - - - - - - - - | 7,155 Calories. |
| Sheep D, - - - - - - - - - - | 6,915 Calories. |

*Fuel Value of Urea Equivalent to Digested Protein.*

| | |
|---|---|
| Sheep A, - - - - - - - - - - | 365 Calories. |
| Sheep B, - - - - - - - - - - | 350 Calories. |
| Sheep C, - - - - - - - - - - | 405 Calories. |
| Sheep D, - - - - - - - - - - | 395 Calories. |

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

| | |
|---|---|
| Sheep A, - - - - - - - - - - | 6,360 Calories. |
| Sheep B, - - - - - - - - - - | 6,970 Calories. |
| Sheep C, - - - - - - - - - - | 7,560 Calories. |
| Sheep D, - - - - - - - - - - | 7,310 Calories. |

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep A, - - - - - - | 9,280 Calories. | 9,905 Calories. |
| Sheep B, - - - - - - | 8,790 Calories. | 9,295 Calories. |
| Sheep C, - - - - - - | 9,865 Calories. | 10,500 Calories. |
| Sheep D, - - - - - - | 10,225 Calories. | 10,750 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep A, 69.1 per cent. of total protein and 60.9 per cent. of total fuel value.
Sheep B, 65.9 per cent. of total protein and 57.1 per cent. of total fuel value.
Sheep C, 66.9 per cent. of total protein and 58.1 per cent. of total fuel value.
Sheep D, 68.6 per cent. of total protein and 59.5 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 9.

(See page 119, this Report.)

*Rowen hay, mostly timothy.*

*Calories per Gram of Water-free Substance.*

| | Laboratory No. | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|---|
| Rowen, - - - - | 1399 | 4.270 | 4.650 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

| | |
|---|---|
| Sheep A, B and C, each, - - - - - - - | 17,165 Calories. |
| Sheep D, - - - - - - - - - - | 15,850 Calories. |

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

| | |
|---|---|
| Sheep A, - - - - - - - - - - | 6,640 Calories. |
| Sheep B, - - - - - - - - - - | 6,790 Calories. |
| Sheep C, - - - - - - - - - - | 6,805 Calories. |
| Sheep D, - - - - - - - - - - | 5,850 Calories. |

*Fuel Value of Urea Equivalent to Digested Protein.*

| | |
|---|---|
| Sheep A, - - - - - - - - - - | 345 Calories. |
| Sheep B, - - - - - - - - - - | 360 Calories. |
| Sheep C, - - - - - - - - - - | 355 Calories. |
| Sheep D, - - - - - - - - - - | 335 Calories. |

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

| | |
|---|---|
| Sheep A, - - - - - - - - - - | 6,985 Calories. |
| Sheep B, - - - - - - - - - - | 7,150 Calories. |
| Sheep C, - - - - - - - - - - | 7,160 Calories. |
| Sheep D, - - - - - - - - - - | 6,185 Calories. |

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep A, - - - - - - | 9,470 Calories. | 10,180 Calories. |
| Sheep B, - - - - - - | 9,115 Calories. | 10,015 Calories. |
| Sheep C, - - - - - - | 9,445 Calories. | 10,005 Calories. |
| Sheep D, - - - - - - | 9 080 Calories. | 9,665 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep A, 66.1 per cent. of total protein and 59.3 per cent. of total fuel value.
Sheep B, 69.4 per cent. of total protein and 58.6 per cent. of total fuel value.
Sheep C, 68.2 per cent. of total protein and 58.3 per cent. of total fuel value.
Sheep D, 68.3 per cent. of total protein and 60.9 per cent. of total fuel value.

## DIGESTION EXPERIMENT NO. 10.

(See page 120, this Report.)

*Scarlet clover hay, field cured.*

*Calories per Gram of Water-free Substance.*

| | Laboratory No. | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|---|
| Scarlet clover hay, - - | 1418 | 4.090 | 4.375 |

*Fuel Value of Total Food Eaten in 5 Days, as Determined by Bomb Calorimeter.*

Sheep A, B, C and D, each, - - - - - - 11,395 Calories.

*Fuel Value of Feces for 5 Days, as Determined by Bomb Calorimeter.*

Sheep A, - - - - - - - - - - 6,330 Calories.
Sheep B, - - - - - - - - - - 6,175 Calories.
Sheep C, - - - - - - - - - - 6,085 Calories.
Sheep D, - - - - - - - - - - 5,880 Calories.

*Fuel Value of Urea Equivalent to Digested Protein.*

Sheep A, B, C and D, each, - - - - - - 240 Calories.

*Total Unused Fuel Value (Feces Plus Urea Equivalent).*

Sheep A, - - - - - - - - - - 6,570 Calories.
Sheep B, - - - - - - - - - - 6,415 Calories.
Sheep C, - - - - - - - - - - 6,325 Calories.
Sheep D, - - - - - - - - - - 6,120 Calories.

*Available Fuel Value of Digested Nutrients.*

| | As Calculated from Analysis. | As Determined by Bomb Calorimeter. |
|---|---|---|
| Sheep A, - - - - - - | 4,740 Calories. | 4,825 Calories. |
| Sheep B, - - - - - - | 4,960 Calories. | 4,980 Calories. |
| Sheep C, - - - - - - | 4,940 Calories. | 5,070 Calories. |
| Sheep D, - - - - - - | 5,160 Calories. | 5,275 Calories. |

*Digested Protein and Available Fuel Value of Food Eaten.*

Sheep A, 63.9 per cent. of total protein and 42.4 per cent. of total fuel value.
Sheep B, 63.9 per cent. of total protein and 43.7 per cent. of total fuel value.
Sheep C, 65.1 per cent. of total protein and 44.5 per cent. of total fuel value.
Sheep D, 64.6 per cent. of total protein and 46.3 per cent. of total fuel value.

TABLE 44.

*Summary.*

| Feeding Stuffs. | Current No. of Experiment. | Sheep. | Fuel Value of Digested Nutrients. Calculated from Analysis. | Fuel Value of Digested Nutrients. Determined by Bomb Calorimeter. | Digested Protein. | Available Fuel Value. |
|---|---|---|---|---|---|---|
| | | | Calories. | Calories. | % | % |
| Bran, corn meal and hay, - - - | 1 | B | 10,625 | 10,615 | 48.0 | 57.6 |
| Bran, corn meal and hay, - - - | 1 | D | 12,050 | 12,230 | 62.1 | 66.4 |
| Bran, corn meal and hay, - - - | 4 | B | 12,540 | 12,390 | 57.6 | 67.9 |
| Bran, corn meal and hay, - - - | 4 | D | 12,045 | 11,895 | 52.2 | 65.2 |
| Average, - - - - - - | — | — | — | — | **55.0** | **64.3** |
| Wheat bran, linseed meal, oat and pea meal, hay, - - - - - | 2 | B | 11,785 | 11,920 | 73.5 | 63.6 |
| | 2 | D | 11,975 | 12,155 | 71.2 | 64.8 |
| Wheat bran, corn meal, linseed meal, oat and pea meal, hay, - - - | 3 | B | 12,585 | 13,120 | 77.1 | 70.3 |
| | 3 | D | 11,850 | 12,200 | 71.6 | 65.4 |
| Average, - - - - - - | — | — | — | — | **73.4** | **66.0** |
| Scarlet clover, fed green, - - - | 5 | A | 9,730 | 10,110 | 76.7 | 63.7 |
| Scarlet clover, fed green, - - - | 5 | B | 9,860 | 10,205 | 77.5 | 64.3 |
| Scarlet clover, fed green, - - - | 5 | D | 7,860 | 8,160 | 77.2 | 64.3 |
| Average, - - - - - - | — | — | — | — | **77.1** | **64.1** |
| Barley fodder, fed green, - - - | 6 | A | 7,415 | 7,935 | 69.3 | 57.8 |
| Barley fodder, fed green, - - - | 6 | B | 8,765 | 9,540 | 71.4 | 66.4 |
| Average, - - - - - - | — | — | — | — | **70.4** | **62.1** |
| Barley and pea fodder, fed green, - | 7 | C | 7,025 | 7,460 | 81.1 | 60.2 |
| Barley and pea fodder, fed green, - | 7 | D | 5,055 | 5,150 | 73.2 | 49.4 |
| Average, - - - - - - | — | — | — | — | **77.2** | **54.8** |
| Rowen hay, mixed grasses, - - | 8 | A | 9,280 | 9,905 | 69.1 | 60.9 |
| Rowen hay, mixed grasses, - - | 8 | B | 8,790 | 9,295 | 65.9 | 57.1 |
| Rowen hay, mixed grasses, - - | 8 | C | 9,865 | 10,500 | 66.9 | 58.1 |
| Rowen hay, mixed grasses, - - | 8 | D | 10,225 | 10,750 | 68.9 | 59.5 |
| Average, - - - - - - | — | — | — | — | **67.7** | **58.9** |
| Rowen hay, mostly timothy, - - | 9 | A | 9,470 | 10,180 | 66.1 | 59.3 |
| Rowen hay, mostly timothy, - - | 9 | B | 9,115 | 10,015 | 69.4 | 58.6 |
| Rowen hay, mostly timothy, - - | 9 | C | 9,445 | 10,005 | 68.2 | 58.3 |
| Rowen hay, mostly timothy, - - | 9 | D | 9,080 | 9,665 | 68.3 | 60.9 |
| Average, - - - - - - | — | — | — | — | **68.0** | **59.3** |
| Scarlet clover hay, field cured, - - | 10 | A | 4,740 | 4,825 | 63.9 | 42.4 |
| Scarlet clover hay, field cured, - - | 10 | B | 4,960 | 4,980 | 63.9 | 43.7 |
| Scarlet clover hay, field cured, - - | 10 | C | 4,940 | 5,070 | 65.1 | 44.5 |
| Scarlet clover hay, field cured, - - | 10 | D | 5,160 | 5,275 | 64.6 | 46.3 |
| Average, - - - - - - | — | — | — | — | **64.4** | **44.2** |

# A NEW FORM OF BOMB CALORIMETER AND DETERMINATIONS OF HEATS OF COMBUSTION.

BY W. O. ATWATER AND CHAS. D. WOODS.

## THE BOMB CALORIMETER.

During the past five years the reports and bulletins of this Station have contained frequent reference to the fuel values of food materials and the need of more definite information regarding not only the potential energy of food, but also the more general subject of the transformation of energy in the living organism.*

The later development of experimental science has given us clearer ideas not only of the chemical, but also of the physical changes that take place in the animal and in the plant. To these processes it has become customary to apply the term metabolism. The processes of metabolism in the body are of two definite but closely allied kinds—the metabolism of matter and the metabolism of energy. It is commonly assumed that these two processes conform, the one to the law of the conservation of matter and the other to that of the conservation of energy. Exactly this form of statement is not usual, but the principles thus enunciated have been more or less definitely assumed by writers and experimenters during the last twenty years or more. The bringing of the metabolic processes into line with these two fundamental laws helps greatly toward simplifying the whole subject, clearing up details that have been obscure, and placing the doctrine of nutrition upon a rational and simple basis. In the light of these laws many of the results of experimenting are more easily interpreted, imperfections in plan and errors in execution of past experimenting are brought out, and the ways in which the unsolved problems before us may best be studied are laid open. Experimenter, teacher, and student alike are helped by such a coördination of principles. At the same time the theory of nutrition thus becomes plainer to the practical man. He can understand it

* See, especially, Report for 1890, p. 174.

more easily if it is put in terms of "flesh formers" and "fuel values" than if he must consider protein, fats, and carbohydrates in the ways which have become so generally current.

Food has two chief functions—to build tissue and serve as fuel. In the building of tissue from food and in the constant breaking up and repair of tissue we have to do with the metabolism of matter. In the service of food and of tissue material as fuel, to yield heat and muscular power, we have to do with the metabolism of energy. The protein compounds are the tissue formers. The fats and the carbohydrates are the chief fuel ingredients; but protein compounds also serve as fuel. In this service as fuel the nutrients replace each other in proportion to their potential energy. The economy of food in nutrition requires sufficient protein for the formation of tissue and sufficient energy for supplying heat and strength. The fuel value of food is thus one of the two chief factors of its value for nutriment.

The fat of the food is stored as fat in the body. The protein and carbohydrates of the food are transformed into body fat. The fuel value of the food thus becomes an indication of its capacity for fat formation.

The fat of the body is its reserve store of fuel. The fuel value of the fats is more than twice as great, weight for weight, as that of the protein or carbohydrates. Fat is body fuel in its most concentrated form. Therein lies the economy of nature in the storage of fat in the body.

Of course the whole doctrine of nutrition is not as simple a matter as these statements would imply, but they do represent its fundamental principles. One important part of the problem is the source of intellectual energy. Doubtless this comes, in some way, from the food, but what it is and how it is produced and what food materials are most efficient for its production are questions that the experimental science of to-day are far from answering.

In the metabolism of matter and energy we have the foundation of the theory of nutrition, the starting point of experimental inquiry, and the means of simplifying the theories which we have to teach. It is thus clear that the experimenter who will study thoroughly the laws of nutrition and the uses and the nutritive values of food must have a means for determining the potential energy of the ingredients of the food and of the compounds of the body which are formed from them. Since this potential energy is measured

by the heat developed when the substances are burned with oxygen he may employ a method for determining the amount of heat thus developed.

But it is not the physiological chemist alone to whom the method and apparatus for measuring heats of combustion is essential. Inquiry in this special field is of fundamental importance in physical chemistry generally, and research has demonstrated its necessity for that understanding of the molecular structure of compounds which has become one of the most important factors of the development of those branches of chemical science to which the terms "organic" and "theoretical" are commonly applied. And finally, the chemical technologist, who is endeavoring to learn the values of coal and other fuel materials for heating, experiences the necessity of a means for determining their heats of combustion. Various forms of calorimetric apparatus have been devised for this purpose.* The Stohmann calorimeter,† which is a modification of that of Thompson, was employed for the studies of heats of combustion by Dr. H. B. Gibson, which were described in the report of this Station for 1890.

In the combustions by the Thompson-Stohmann method the oxygen is obtained from potassium chlorate. Considerable time is required for the determination, but the chief difficulty with this method is that the combustion is not always complete.

## THE BERTHELOT BOMB CALORIMETER.

Berthelot has devised an apparatus‡ and, with the assistance of Vieille and others, has developed a method for the use of oxygen under high pressure. The apparatus consists essentially of a steel bomb lined with platinum, within which the substance is burned. The bomb is immersed in water contained in a metal cylinder; this calorimeter cylinder is placed with its contents inside of concentric cylinders containing air and water. The heat developed

* See discussion of the general subject of metabolism of energy in the body and descriptions of calorimeters in Bulletin 21 of the Office of Experiment Stations of the U. S. Department of Agriculture, from which portions of the statements herewith regarding bomb calorimeters are taken. The engravings of the calorimeter beyond are from the same publication and are used here by courtesy of the Department.

† This apparatus is described in the Bulletin just referred to. See also the original description by Stohmann, with diagram; Landw. Jahrbücher, 13, 1884, 513. The apparatus is pictured in the Century Magazine for July, 1887.

‡ For descriptions see Berthelot, Ann. Chim. Phys. (5), 23, 160; Berthelot & Vieille, ibid., (6) 6, 546 Berthelot, Traité pratique de calorimétrie chimique, Paris, 1893, p. 128, and, for an especially clear account of the apparatus and method, Stohmann, Jour. f. prak. Chem., 147 (N. F. 39), 1889, 503. An engraving of the bomb with a brief description may be found in Fres. Zeitsch. Anal. Chem., 1893, 77. A Berthelot apparatus employed by Stohmann was obtained from Golaz in Paris, who made it in accordance with Berthelot's directions. It cost, with accessories, including compression pump, etc., not far from $1,200. Aside from those used in Berthelot's laboratory and the one made for Stohmann, extremely few have been made.

is measured by the rise in temperature of the water, due allowance being made for the heat absorbed by the metal of the apparatus and for that introduced in igniting the substance by an electric current and developed by the oxidation of an iron wire through which the current is passed, and in the formation of a small amount of nitric acid. The reactions are simple, the oxidation of the compounds in completing the determination requires a comparatively short time, and the results are very satisfactory. The only drawback is the great cost of the apparatus, which is due to the large amount of platinum employed in its construction. It is doubtless because of this that the bomb, which is most useful for its purpose and would be highly prized in many laboratories, has not come into common use.

The bomb calorimeter was first used by Berthelot in measuring the heats of combustion of gases by detonation. The gas to be burned was mixed with the exact amount of oxygen required, or a slight excess, at ordinary atmospheric pressure within the bomb and ignited by the passage of an electric spark. Gases were easily burned in this way, but the combustion of solids was impracticable. Attempts were made to remedy the difficulty with solids by intimately mixing them with potassium chlorate and as good results were obtained as in the Thompson-Stohmann method. Berthelot and Vieille* found later,† however, that when oxygen was introduced under a pressure of from 7 to 25 atmospheres, the combustion was complete with all organic substances even when no potassium chlorate was added.

The bomb originally employed by Berthelot was in the shape of a cylinder, with hemispherical ends and divided in two parts, one of which screwed into the other. It was made of steel with the interior lined with gold by electro-plating.

The later and permanent form of Berthelot's bomb is cylindrical with a rounded bottom and flat cover. It is made of steel with a heavy lining of platinum. The size may vary. In the one made by Golaz for Stohmann the diameter is approximately 10 centimeters and the height to the upper surface of the cover about 13 centimeters; the walls are somewhat over a centimeter in thickness. It contains 2,717 grams of steel and 1,233.3 grams

* Ann. Chim. Phys., (6) 6, 546.

† In 1885. The principle was discovered and investigated by Frankland in 1864 and 1868. See investigations by him "On the combustion of iron in compressed oxygen." Jour. Chem. Soc. II., 1864; 52. "On the combustion of gases under pressure." Brit. Assoc. Rep. XXXVIII., 1868 *(Sect.)*; 37. "On the combustion of hydrogen and carbonic oxide in oxygen under great pressure." Proc. Roy. Soc. XVI., 1868; 419.

of platinum. The internal capacity is about 300 cubic centimeters and it holds, under a pressure of 24 atmospheres, 7 liters, or, in round numbers, 10 grams, of oxygen. The cover fits into the top of the cylinder after the manner of a stopper. It is pressed in and held very tightly by an outer cap or collar which screws on to the outside of the cylinder at the top. The fittings have to be made with the greatest care in order to prevent the escape of gas. The material to be burned is shaped into a small cake by means of a powerful press and is held in a platinum capsule. This capsule is sustained by a platinum wire which is fastened to the under side of the cover. Another platinum wire passes through the cover, from which it is insulated by gutta percha, or other appropriate material. These two wires are so arranged that they are easily connected by a piece of fine iron wire hanging over the substance to be burned in the platinum capsule. An electric current passed through the platinum wire heats the iron wire to a temperature where it burns in the oxygen and, melting, falls upon the substance so as to ignite it. An arrangement at the top of the cover provides for admitting the oxygen. The oxygen is introduced either with the aid of a compression pump, or, more conveniently, from iron or steel cylinders, in which it is held under sufficient pressure. Both Berthelot and Stohmann use such cylinders without the aid of a pump. Experience has shown that it is desirable to have fully three times as much oxygen present as is theoretically necessary for the combustion.

The quantity of water in which the bomb is immersed is generally about 2 liters. It is contained in a calorimeter cylinder of brass or other metal. A stirrer, not easily described without a diagram, plays between the bomb and the cylinder in such a way as readily to mix the water and insure uniform temperature after the combustion. The outer cylinders which are employed by Berthelot and Stohmann to protect the apparatus from gain or loss by heat outside, as above described, are made of copper. They find that two concentric cylinders so arranged as to hold a layer of water between them, the inner being large enough to leave a considerable air space around the calorimeter cylinder, suffice for accurate work.

In Stohmann's laboratory the arrangements to insure accuracy are quite elaborate. The work is done in a basement room surrounded by very thick walls of stone. Special devices are

employed to keep the temperature of the room exactly constant. The stirrer is moved by a small motor, which is so regulated as to make the movement the same for all determinations. Berthelot uses a motor for the stirring, but conducts the combustion in the laboratory rooms where other work is done and without special arrangements to insure uniform temperature.

The Berthelot bomb calorimeter serves its purpose admirably. It is comparatively simple, easily handled, and does not get out of order when properly cared for. Practically all kinds of ordinary organic compounds are completely oxidized when the proper excess of oxygen is used at an initial pressure of 25 atmospheres. With an accurate thermometer the rise in temperature of the water is measured with great accuracy. The corrections, of which the chief is the thermal water equivalent of the apparatus, are not particularly difficult to determine. The skill and care required in the manipulation are not beyond any thoroughly expert operator, and the results are very satisfactory indeed, as may be seen by comparing those obtained by Berthelot and Stohmann in determining the heats of combustion of the same material in their respective laboratories.

The steel of which the bomb is made is especially exposed to corrosion. Berthelot protects the outside of the bomb by plating with nickel which serves the purpose very well, as water and air are practically the only corrosive agents to which it is exposed. But with the interior the case is very different. The oxygen at high pressure is very active in itself. The carbon, sulphur, and phosphorus of the substances burned are completely oxidized, and carbonic, sulphuric and phosphoric acids are formed. Indeed, Berthelot has shown that the apparatus may be used for determining carbon, sulphur and phosphorus in these forms. More or less of the free nitrogen which is mingled with the oxygen used in the combustion and perhaps, at times, some of the nitrogen of the substance burned is oxidized and forms nitric acid. It is necessary that the inner surface be covered with some substance which will resist these acids as well as the oxygen. Such materials are easily found, but the practical difficulty has been to find an inexpensive lining which will insure permanent protection to the steel. In Berthelot's first bomb, electro-plating with platinum was tried, but the plantinum soon began to scale off. After a few combustions gold was substituted for platinum and with better success, but it has not been used with oxygen under

pressure. The outcome of the experience was the use of a lining of platinum one-half millimeter in thickness.

### THE BOMB CALORIMETERS OF MAHLER AND OF HEMPEL.

Various modifications of Berthelot's apparatus have been devised especially to obviate the difficulty of expensive lining. Mahler uses a bomb of forged steel with enamel lining.* The cylinder is somewhat narrowed at the top and the cover is screwed directly upon it, the junction being made tight by a washer of lead. The enamel is easily put on or replaced, and it is stated that a single coating has been used for 300 combustions without injury. I have understood, however, that the enamel is apt to scale off in constant use. The form described by Mahler has an internal capacity of 600 cubic centimeters or nearly double that of Berthelot's bomb, as above described.

Prof. Hempel of Dresden uses, for determination of heats of combustion of coal, a simple bomb of steel without lining. The principle, like that of Mahler's form, is the same as that of Berthelot. The closure is by a "head piece" which screws into the neck of the bomb. It suffices very well for technical purposes but is not recommended for scientific use.†

### THE BOMB CALORIMETER HERE USED.

In accordance with suggestions by one of us during a sojourn in Dresden, Prof. Hempel most kindly had a bomb made by the mechanicians who make the bombs of his devising just referred to and lined, by Heraeus of Hanau, with a thin sheet of platinum. Through Prof. Hempel's pains-taking care added to his inventive skill and his peculiarly thorough familiarity with the whole subject, an apparatus was obtained which has proved most efficient. The principle is the same as Berthelot's form; but whereas Berthelot's cover fits into the cylinder in the manner of a very wide stopper, the cover in this, as in Mahler's, rests directly upon the upper edge of the cylinder, a projection of the latter fitting into a groove in the former. A washer of lead is set in the groove of the cover, the latter is held tightly to the cylinder by a screw cap or collar and thus perfect closure is easily secured. The apparatus differs but slightly from that depicted in figure 1 herewith.

* Compt. rend., 113, 774 and 862, and Génie Civile, Jan. 23, 1892, p. 198. See also Zeitsch. f. anal. Chem., 1893, 79, and Berthelot, Calorimétrie Chimique, 133.

† Hempel, Gasanlytische Methoden, 1890, 355 and English translation, Methods of Gas Analysis, 1892, p. 359.

In Berthelot's bomb, as I am informed by the maker, it is found necessary to use a large amount of platinum in the stopper to make it firm, so that although the platinum lining of the cylinder below the neck is only about one-half millimeter thick, over a kilogram of platinum is required for the whole. This simple substitution of a platinum-lined steel cover saves the larger part of the platinum. The cost of the bomb in Dresden, with accessory apparatus, including vise-grip and lever for screwing on the collar, a cylinder for compressed oxygen, fittings, manometer and a screw press* for making hard pellets of the substance to be burned, was less than $220. The apparatus has been in use in our laboratory for more than two years, all the combustions of which the results are given in the present Report were made with it, and we have found it very satisfactory.

The bomb as just described might be recommended for general use in place of the very expensive form devised by Berthelot. Our experience has, however, suggested some alterations, and the attempt is being made, to develop an apparatus which, without sacrifice of accuracy and reliability, will be durable, convenient and capable of being made at a cost which will bring it within the reach of ordinary laboratories. The efforts in this direction are being materially aided by the U. S. Department of Agriculture. The results thus far are very encouraging, but we are not yet certain what kind of metal will ultimately prove best for the bomb or for the lining, and there are numerous details of construction and manipulation which still need to be worked out and tested.

The main objective point at present is to diminish the cost of the lining. Whether this will be best accomplished by a cheaper lining of platinum, or by a lining of another metal, or by using a less corrosive metal than steel for the bomb and thus avoiding the lining altogether, remains to be seen. But there is no doubt as to the feasibility of making an excellent bomb of steel with a thin platinum lining.

Two steel bombs have been made by the Pratt & Whitney Co. of Hartford, Conn., and to whose personal interest in the matter, with that of Mr. G. M. Bond of their establishment, especial thanks are due. Their facilities for making such apparatus are very unusual in respect to mechanical appliances,

* As used by Hempel, loc. cit.

large experience, critical appreciation of the scientific demands, and means for insuring accuracy and finish of execution. Figure 1 herewith represents the last form of bomb adopted. It differs from the first one and from the one made in Germany as above described, chiefly in the introduction of the ball-bearings (K K).

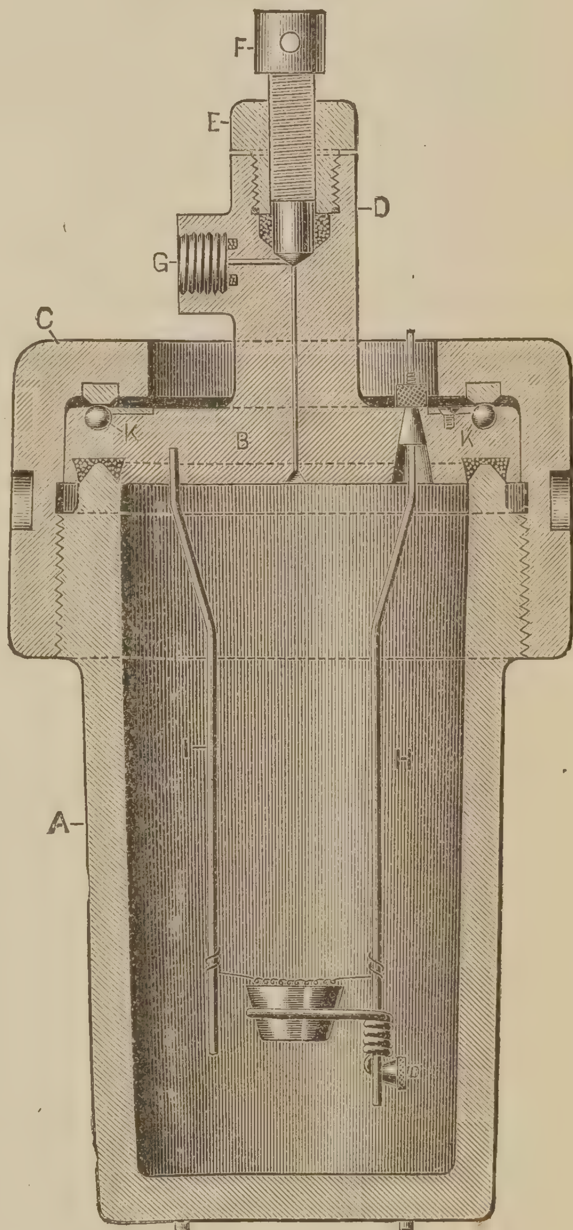

FIG. 1.—CALORIMETER BOMB.

A represents the cylinder, B the cover, and C the screw cap or collar by which the cover is held on the cylinder. The cover is provided with a neck (D). Into this fits, at the top, a cylindrical screw (E), into which in turn fits a valve screw (F). In the neck (D), where the bottom of the cylinder screw (E) rests, is a shoulder fitted with a washer of lead. On the side of D is an opening (G), into which may be screwed a tube connected with the receptacle which holds the oxygen used for the combustion. The tube when screwed in thrusts against a washer of lead at the end of G, which insures perfect closure. A narrow passage runs horizontally to the center of D, and then perpendicularly downwards through the cover, and thus provides passage for the oxygen to the interior of the bomb. This passage may be tightly closed by the valve screw, the lower end of which is conical and thrusts against the inner surface of D, the angle of which at the place of contact corresponds to that of the tip of the screw. The upper edge of A is beveled on both sides, the apex being rounded, and fits into a washer of soft metal, which is held in a groove in the cover (B). Washers of lead have been used thus far. They yield to the heavy pressure and the metal gradually flows out of

the groove with use, so that the washers have to be replaced occasionally. With an instrument devised by Prof. Hempel a new washer can be cut out of a thick sheet of lead and inserted in a short time. We are, however, trying a washer of copper which will not flow so easily.

One difficulty in screwing the collar down tightly enough to prevent the escape of gas between the edge of the cylinder and the washer at the high pressure to which the gases are subjected, has been the friction of the collar upon the cover. To accomplish this the cylinder of the bomb is put in a clamp, which is fitted to the cylinder and is held in a vise. The collar is turned by a long-handled spanner, the projection of which fits into the two depressions shown in the collar. Even with a spanner handle nearly three-quarters of a meter in length, much force is needed to secure tight closure. To avoid the friction between the collar and the cover, ball-bearings (K K) of very hard steel, such as are employed for bicycles, are used in the last bomb made. These run in a groove in the cover and are kept from falling out by a flat ring which is easily removed. The bearing in the collar which comes against them, as shown in the picture, is also of hard steel.

The platinum wires, H and I, inside the bomb, serve to hold a platinum capsule containing the substance to be burned and to transmit an electric current. Of these two wires one, I, is screwed into the cover; the other, H, passes through a conical hole in the cover from which it is insulated by a piece of vulcanized rubber, in the shape of a frustum of a cone and fits the hole. A small nut screwed on the platinum wire at the upper surface of the cover draws the wire and with it the vulcanized rubber cone tightly into the hole and holds them in place. Near the lower end of H is a platinum wire bent in the form of a ring to hold the platinum capsule and coiled about the wire, to which it is held by a screw. When a combustion is made the two platinum wires are connected by a very fine iron wire which passes over the crucible. The part directly above the substance to be burned is bent into a spiral, thus furnishing a larger quantity of iron to be ignited and, falling, to ignite the substance in the crucible. The cylinder is approximately 12.5 centimeters deep and 6.2 in diameter inside. The wall is approximately .5 of a centimeter in thickness. The weight of the whole bomb is approximately 2,900 grams and its capacity nearly 380 cubic centimeters.

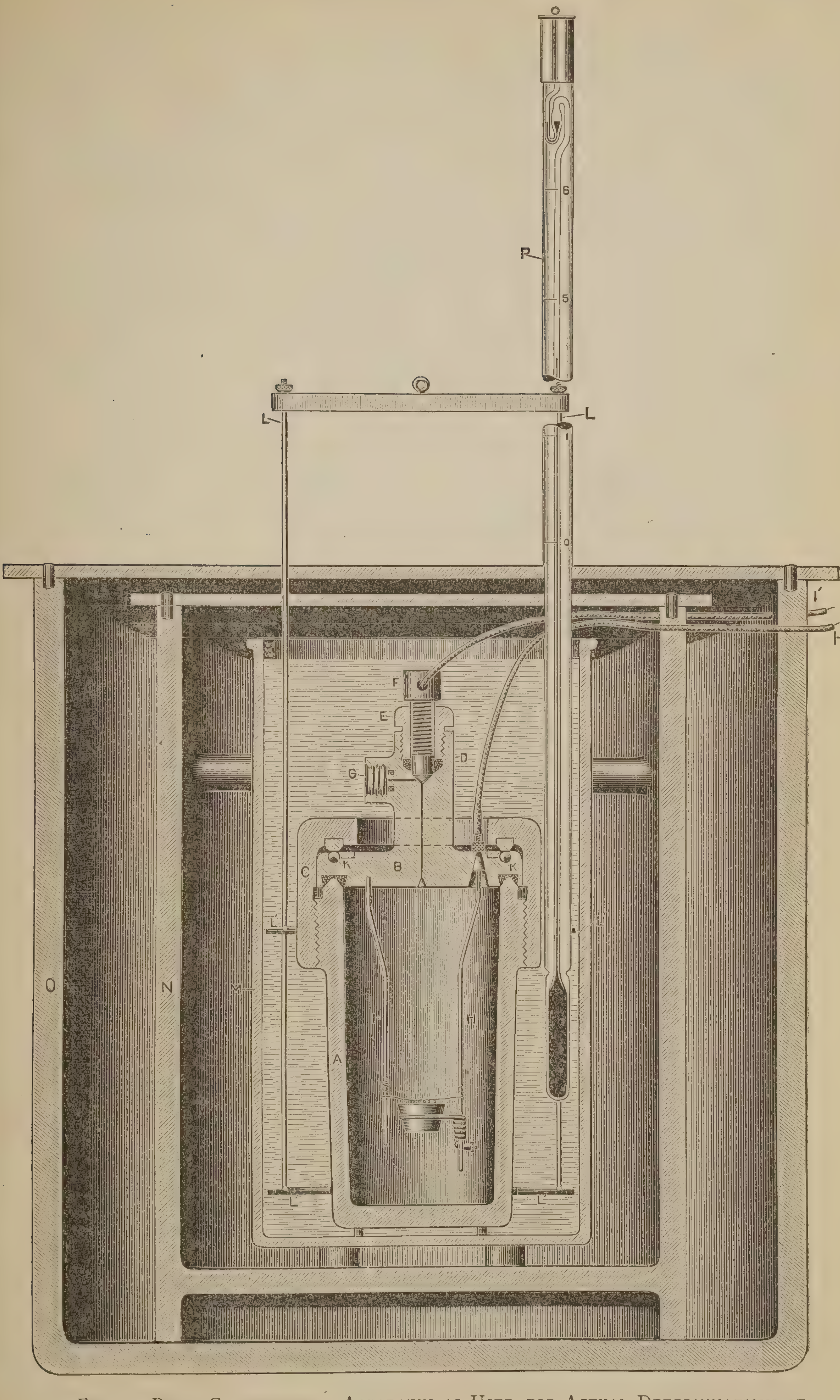


FIG. 2.—BOMB CALORIMETER; APPARATUS AS USED FOR ACTUAL DETERMINATIONS OF HEATS OF COMBUSTION.

The apparatus as set up for the combustion is shown in figure 2. M is the calorimeter cylinder. Those employed by Berthelot and Stohmann are made of brass. We have found the ordinary "white metal" used in making silver plated ware, which is essentially an alloy of tin, copper and antimony, well adapted to the purpose. This is large enough to hold the bomb and two liters of water, the water rising just to the top of the valve screw and very near to the top of the cylinder. L L is a stirrer which is moved up and down and thus brings the water to a uniform temperature. The calorimeter cylinder is contained in two larger concentric cylinders. In the apparatus as used by Berthelot and by Stohmann these are made of copper. They may be so joined that the space between the inner and outer one can be kept filled with water and thus effectually prevent the passage of heat from without inward. We have used cylinders of ordinary indurated fiber, N and O, with air spaces between. The indurated fiber is a good non-conductor of heat and we have found the arrangement satisfactory. Each of the two cylinders has a cover of vulcanized rubber. Beneath and on the sides of the calorimeter cylinder are supports of cork which keep it in place and prevent contact with cylinder N. The vulcanized rubber covers are each provided with two small holes through which pass the two upright rods of the stirrer and a larger hole for the thermometer P. In the sides of the two cylinders N and O near the top are holes through which pass wires H and I, to connect the platinum wires H and I with an electric battery. The whole apparatus is shown in cross section in figure 3. In this one of the flat, horizontal rings of the stirrer L is shown. This is wide enough to nearly fill the space between the bomb and the cylinder, but has a number of holes so that when it is moved up and down the water is not unduly agitated. One side is cut away to make room for the thermometer.

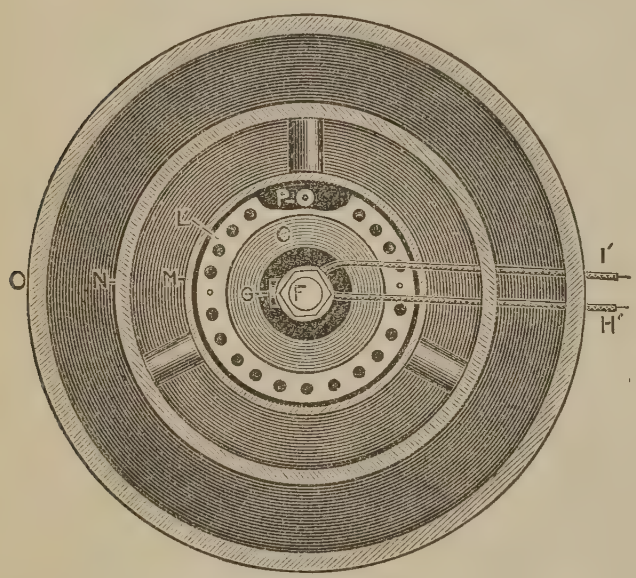

Fig. 3.—Cross Section of Bomb Calorimeter Apparatus.

The cross bar at the top of the stirrer, shown in figure 2, has in the center a small ring. To this is attached a cord which connects with a wheel above. By the slow revolution of the latter the stirrer is raised and then allowed to fall by its own weight. The wheel is moved by a motor at nearly uniform rate so that the amount of motion of the stirrer in a given time is always nearly the same. The cross bar is held to the upright rods by nuts and is easily removed when the covers of N and O are taken off and put on.

The temperature of the water is measured by the thermometer P. We have several thermometers for this purpose. All are graduated to hundredths of a degree. One, which we employ as a standard thermometer for correcting the others and which is also very convenient for regular use, was made by Fuess and calibrated by the Physikalischtechnische Reichsanstalt in Berlin. The scale, which is 25 centimeters long, covers six degrees marked from 0 to 6. Each degree is divided into hundredths, and the divisions are of such length as to permit of easy estimates of thousandths by the aid of a magnifying glass. We are persuaded that, in this way, measurement of the temperature of the water to thousandths of a degree can be made with as close an approach to accuracy as the weighings to the tenths of a milligram with an ordinary laboratory balance. This especial thermometer is provided with a Boeckmann reservoir at the top into which a part of the mercury can be driven at will. The readings, therefore, as marked from 0 to 6 on the thermometer, may indicate actual temperatures from the freezing to the boiling point of water according as little or much mercury is driven into the reservoir. The thermometer is calibrated for measurements at any of these temperatures. The cost of the thermometer in Berlin was 37.50 marks, the charge for calibrating was 21 marks, making total cost in Berlin about $17. We have found it very satisfactory.

The accessory apparatus consists of a screw press of the kind used by Hempel* for compressing the substance to be burned into a firm cylindrical cake, vise, vise-grip, lever for screwing the cap, a cylinder of compressed oxygen with tubes and manometer for filling the bomb, an electrical apparatus to furnish a current for igniting the substance (we connect directly with an electric lighting circuit, using a resistance coil to reduce the

* Gas Analysis, page 356.

current,) and the arrangement above referred to for moving the stirrer. The manipulation requires the same skill that is demanded for accurate laboratory determinations in general and no more. The actual process is briefly as follows: The substance to be burned is, when convenient, pressed into a cake, and, after weighing, put in the small platinum capsule; the latter is then placed in the ring support under the small iron wire connecting the two platinum wires H and I. The bomb cover, which holds these wires and with them the capsule, is then put on the cylinder, the collar is screwed on, the oxygen is introduced until the pressure indicates at least 20 atmospheres. The bomb is then put in the calorimeter cylinder inside the larger cylinders; the covers, stirrer, thermometer, and connecting wires H and I are properly arranged; and the apparatus is allowed to stand, generally for not more than three minutes, until the temperature of the water, which at the outset is two degrees or a little more below that of the room, begins to rise. Six initial readings are then taken at intervals of one minute, these generally show a rise of from two to four hundredths of a degree. At the moment of the sixth reading, which is taken for the initial temperature of water and apparatus, the current is turned on, the wire is ignited at the same moment and falls, igniting the substance. The combustion takes place quickly but quietly, and the temperature forthwith begins to rise. The thermometer is read for five minutes at intervals of one minute and again after ten minutes more. The first of the initial readings, the one at the moment of turning on the current, the five which follow and the last one are used in a formula* for computing the correction for the influence of the temperature of the air in the room upon the change in temperature of water and apparatus during the combustion. The result shows the actual rise of temperature of water and apparatus (bomb, calorimeter cylinder, stirrer and thermometer) due to the combustion. The next steps are to find the number of calories of heat which correspond to the rise of temperature of water and apparatus and then the calories of heat actually developed by the combustion of the substance. For the first it is necessary to know the thermal water equivalent of the apparatus. This has to be determined for each apparatus and under the circumstances in which it is to be used. The methods here followed are essentially those described by Stohmann, Kleber and Langbein.† The quantity of water thus

* The formula here used is essentially the same as developed by Stohmann, Kleber and Langbein, Jour. f. prac. Chem., 147, 1889, 517-523. † Loc. cit. 524-536.

found to be thermally equivalent to the apparatus is added to the quantity of water actually used. The specific heat of this amount of water, compared with the rise in temperature as above determined, gives the actual number of calories of heat contributed to water and apparatus by the combustion. The total heat thus contributed includes the heat of combustion of the substance itself plus the heat of oxidation of the iron wire and the heat of formation of a certain amount of nitric acid, which is at the same time produced in small but varying quantity. To determine the heat of oxidation of the iron each wire is weighed at the outset, When, as is sometimes the case, a portion is left unoxidized, this is weighed at the end and the difference is taken as the amount oxidized. The purest piano wire is used and the heat produced is estimated from the amount oxidized and the otherwise observed heat of oxidation of iron (for $Fe_3 O_4$ 1,600 small calories per gram of Fe). The nitric acid which is dissolved in the water formed by the combustion in the bomb is rinsed out and the amount is determined by titration with a standard solution of sodium carbonate, one cubic centimeter of which will neutralize a quantity of nitric acid of which the heat of formation is one small calorie. Adding the heats due to the oxidation of the iron and the formation of nitric acid and subtracting the sum from the total heat communicated to the apparatus and water leaves the amount due to the oxidation of the substance.

There are, of course, numerous details of manipulation suggested by experience which hardly need be described here. One for instance is the use of a kindling material for animal and vegetable fats, in which the molten globule of iron oxide sometimes sinks until it is covered without igniting the substance. By laying a small portion, three to five milligrams, of naphthalene on top of the substance, ignition is made sure. Allowance is made for the heat of combustion of the naphthalene, which, for that we have used, is found to be 9,678 small calories per gram.

One essential feature is the oxygen. This we formerly obtained from Berlin, but it can now be had in New York, of satisfactory purity, in cylinders ready for use. With only a single cylinder, a force pump would be necessary to charge the bomb as soon as the pressure in the cylinder should fall below 20 atmospheres, which is the pressure required in the bomb. To avoid the necessity of a force pump we employ two cylinders with a device

by Stohmann, which consists of tubes and gas cocks so arranged that either cylinder can be connected with the bomb or disconnected without trouble. A manometer is joined to the tube leading to the bomb. One cylinder alone is used for charging until the pressure falls below 20 atmospheres. Thereafter, in charging, the oxygen is allowed to run from this cylinder into the bomb until the pressure is the same in both; the connection then is shut off and the other cylinder, in which the pressure is higher, is connected with the bomb and the charging up to 20 atmospheres is completed. In this way the oxygen in the first cylinder can be used until the pressure is reduced to one atmosphere. The cylinder is then sent away to be refilled. We find it convenient to have three cylinders and are thus never without at least one with sufficient pressure for charging.

The results of our experience thus far may be briefly summarized.

1. As to apparatus. The bombs we have had made at home as above described seem to promise better than anything we should be able to obtain from European makers. The strongest and best gun steel is to be had in this country and the workmanship is better than anything we have seen in apparatus of the kind made in France or Germany. We are not yet certain that the platinum lining can be more advantageously provided here than in Germany though that now seems probable. We are attempting to find a way to put on the lining by electroplating, using another metal between the steel and the platinum. If this proves successful it will materially lessen the cost; if it does not, a lining of sheet platinum can be used. We hope that it will prove feasible to use some cheaper metal than platinum for lining the steel bomb or to use some non-corrosive metal in the place of the steel for the whole bomb and thus avoid the lining entirely, but are not yet able to speak of the prospect of success. The accessory apparatus is simple and easily obtained.

There is therefore no doubt that an accurate, convenient, reasonably durable and inexpensive bomb calorimeter with the accessory apparatus can be made available to those who have occasion to use it.

2. As to method. To determine the thermal equivalent of the apparatus is a somewhat difficult and time-consuming operation, but when that is done and the schedules for noting the observations and the formulas for calculating the results are made out and the method of manipulation is well in hand, the

determinations of heats of combustion can be made quite rapidly and with a high degree of accuracy. Each determination of a heat of combustion involves: (1) either three or four weighings; one of the calorimeter cylinder and water to insure the right amount of the latter, one of the substance, one of the iron wire, and sometimes one of a small portion of the iron wire left unoxidized; (2) twelve observations of temperature of which eight are actually used; (3) one titration of nitric acid with standard alkali. The calculations for one determination can be made in the intervals of waiting between the observations of temperature of the next one. When the materials of which the heats of combustion are to be determined are ground and prepared for weighing in advance it is not difficult to make nine determinations and calculations in a working day of seven and one-half hours. The accuracy of the results is very satisfactory. Not only do duplicates agree with the greatest closeness, but we have made a considerable number of determinations with pure substances such as sugar, and have obtained results practically identical with those obtained by Berthelot and by Stohmann for the same substances. This identity of results obtained in the three laboratories is certainly very favorable for their correctness and for the reliability of the apparatus and method.

Table 45 gives the results of a considerable number of determinations of the heats of combustion of different foods and feeding stuffs made by the method and with the apparatus above described in the course of investigations here. Many of the combustions here reported were made by Dr. R. L. Slagle, whose skill and accuracy call for especial recognition. The special purpose in collating them is to compare the fuel values as obtained from calculation from the analysis and as determined by the bomb calorimeter. In calculating the potential energy each gram of protein is taken at 5.5 Calories, each gram of fat at 9.3 and each gram of carbohydrates at 4.1 Calories. The difference between the 5.5 Calories here used for one gram of protein and the factor 4.1* which we have ordinarily assumed is explained by the allowance made for the nitrogenous materials which are incompletely consumed in the body.

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* See Report of this Station, 1890, pp. 177, 178.

TABLE 45.

*Fuel Value Per Gram of Water-free Substance of Foods, Feeding Stuffs and Undigested Residues as Determined in the Bomb Calorimeter. (The Results of Analyses and the Calculated Fuel Values are also given for comparison.)*

| FOOD MATERIALS. | Laboratory Number. | Protein. | Fat. | CARBOHYDRATES. Fiber. | CARBOHYDRATES. Nitrogen-free Extract. | Ash. | FUEL VALUE PER GRAM. As Calculated. | FUEL VALUE PER GRAM. As Determined. |
|---|---|---|---|---|---|---|---|---|
| ANIMAL FOODS. | | % | % | % | % | % | Cal. | Cal. |
| *Beef.* | | | | | | | | |
| Porterhouse steak, | 478 | 36.8 | 61.4 | — | | 1.8 | 7735 | 7780 |
| Porterhouse steak, | 576 | 51.8 | 45.6 | — | | 2.6 | 7085 | 7160 |
| Porterhouse steak, | 590 | 37.2 | 60.8 | — | | 2.0 | 7705 | 7860 |
| Average, | — | **41.9** | **56.0** | — | | **2.1** | **7510** | **7600** |
| Sirloin steak, | 488 | 47.4 | 50.1 | — | | 2.5 | 7265 | 7355 |
| Sirloin steak, | 484 | 49.8 | 47.5 | — | | 2.7 | 7155 | 7230 |
| Average, | — | **48.6** | **48.8** | — | | **2.6** | **7210** | **7295** |
| Shoulder steak, | 539 | 56.5 | 39.3 | — | | 4.2 | 6760 | 6940 |
| Shoulder steak, | 562 | 65.9 | 30.6 | — | | 3.5 | 6475 | 6625 |
| Shoulder steak, | 567 | 69.0 | 27.4 | — | | 3.6 | 6340 | 6405 |
| Shoulder steak, | 570 | 71.3 | 24.7 | — | | 4.0 | 6225 | 6395 |
| Average, | — | **65.7** | **30.5** | — | | **3.8** | **6450** | **6590** |
| Round steak, | 532 | 63.1 | 33.5 | — | | 3.4 | 6585 | 6705 |
| Round steak, | 577 | 76.9 | 18.9 | — | | 4.2 | 5985 | 6150 |
| Round steak, | 584 | 65.7 | 30.7 | — | | 3.6 | 6470 | 6600 |
| Average, | — | **68.6** | **27.7** | — | | **3.7** | **6345** | **6485** |
| Rib roast, | 489 | 33.4 | 64.9 | — | | 1.7 | 7875 | 7925 |
| Rib roast, | 496 | 35.5 | 62.8 | — | | 1.7 | 7790 | 7845 |
| Rib roast, | 540 | 63.5 | 33.5 | — | | 3.0 | 6610 | 6740 |
| Rib roast, | 555 | 64.6 | 32.1 | — | | 3.3 | 6540 | 6690 |
| Rib roast, | 566 | 63.5 | 32.8 | — | | 3.7 | 6545 | 6720 |
| Average, | — | **52.1** | **45.2** | — | | **2.7** | **7070** | **7185** |
| Liver, | 493 | 71.5 | 17.2 | 6.4 | | 4.9 | 5795 | 5970 |
| Canned corned beef, | 541 | 57.8 | 33.6 | — | | 8.6 | 6305 | 6415 |
| Dried smoked bologna, | 535 | 38.1 | 45.1 | 5.4 | | 11.4 | 6510 | 6540 |
| *Veal.* | | | | | | | | |
| Leg, | 483 | 60.8 | 35.9 | — | | 3.3 | 6680 | 6580 |
| Rib, | 542 | 82.1 | 13.4 | — | | 4.5 | 5765 | 5840 |
| Rib, | 565 | 75.5 | 20.5 | — | | 4.0 | 6060 | 6180 |
| Rib, | 579 | 61.9 | 34.6 | — | | 3.5 | 4445 | 6720 |
| Average, | — | **73.2** | **22.8** | — | | **4.0** | **5425** | **6245** |
| Loin, | 578 | 88.5 | 6.3 | — | | 5.2 | 5440 | 5565 |
| *Mutton.* | | | | | | | | |
| Chops, | 485 | 37.6 | 60.3 | — | | 2.1 | 7680 | 7780 |
| Chops, | 495 | 30.1 | 68.3 | — | | 1.6 | 8005 | 8060 |
| Average, | — | **33.8** | **64.3** | — | | **1.9** | **7845** | **7920** |
| Leg, | 490 | 36.6 | 61.3 | — | | 2.1 | 7715 | 7740 |
| Leg, | 537 | 60.2 | 36.4 | — | | 3.4 | 6695 | 6855 |
| Average, | — | **48.4** | **48.9** | — | | **2.7** | **7205** | **7300** |

TABLE 45.—*(Continued.)*

| Food Materials. | Laboratory Number. | Protein. | Fat. | Carbohydrates. Fiber. | Carbohydrates. Nitrogen-free Extract. | Ash. | Fuel Value per Gram. As Calculated. | Fuel Value per Gram. As Determined. |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | Cal. | Cal. |
| *Pork.* | | | | | | | | |
| Chops, - - - - - | 482 | 32.1 | 66.1 | — | | 1.8 | 7915 | 8055 |
| Chops, - - - - - | 486 | 29.3 | 69.1 | — | | 1.6 | 8035 | 8140 |
| Chops, - - - - - | 497 | 31.9 | 66.2 | — | | 1.9 | 7910 | 7870 |
| Average, - - - - - | — | **31.1** | **67.1** | — | | **1.8** | **7955** | **8020** |
| Bacon, - - - - - | 492 | 10.4 | 86.1 | — | | 3.5 | 8575 | 8625 |
| Smoked ham, - - - | 536 | 62.4 | 24.5 | — | | 13.1 | 5715 | 5790 |
| Smoked ham, - - - | 538 | 46.4 | 39.9 | — | | 13.7 | 6260 | 6200 |
| Smoked ham, - - - | 553 | 41.0 | 48.3 | — | | 10.7 | 6745 | 6700 |
| Smoked ham, - - - | 569 | 43.2 | 45.2 | — | | 11.6 | 6575 | 6540 |
| Average, - - - - - | — | **48.2** | **39.5** | — | | **12.3** | **6325** | **6310** |
| Salt pork, - - - - | 531 | 4.6 | 91.7 | — | | 3.7 | 8780 | 8885 |
| Salt pork, - - - - | 561 | 2.1 | 94.4 | — | | 3.5 | 8895 | 8885 |
| Average, - - - - - | — | **3.4** | **93.0** | — | | **3.6** | **8840** | **8885** |
| Turkey, right side, - - | 487 | 37.4 | 60.9 | — | | 1.7 | 7720 | 7670 |
| Turkey, left side, - - | 491 | 38.6 | 59.6 | — | | 1.8 | 7665 | 7595 |
| Average, - - - - - | — | **38.0** | **60.3** | — | | **1.7** | **7695** | **7630** |
| Fresh cod, - - - - | 554 | 91.9 | 2.4 | — | | 5.7 | 5280 | 5535 |
| Oysters, - - - - - | 563 | 62.1 | 10.2 | 19.0 | | 8.7 | 5145 | 5290 |
| Cottolene, - - - - | 552 | — | 100.0 | — | | — | 9300 | 9560 |
| Eggs, - - - - - - | 494 | 42.1 | 54.1 | — | | 3.8 | 7345 | 7065 |
| Eggs, - - - - - - | 568 | 54.8 | 41.6 | — | | 3.6 | 6885 | 7015 |
| Average, - - - - - | — | **48.4** | **47.9** | — | | **3.7** | **7115** | **7040** |
| *Dairy Products.* | | | | | | | | |
| Cream cheese, - - - | 543 | 36.0 | 45.5 | 13.2 | | 5.3 | 6750 | 6715 |
| Butter, - - - - - | 4145 | .8 | 95.1 | — | | 4.1 | 8890 | 8870 |
| Butter, - - - - - | 4150 | .8 | 96.0 | — | | 3.2 | 8965 | 9000 |
| Butter, - - - - - | 4158 | 1.3 | 92.0 | — | | 6.7 | 8630 | 8030 |
| Average, - - - - - | — | **1.0** | **94.4** | — | | **4.6** | **8830** | **8635** |
| Milk, - - - - - - | 4143 | 25.3 | 35.3 | 33.8 | | 5.6 | 6060 | 6075 |
| Milk, - - - - - - | 4144 | 25.2 | 32.7 | 36.0 | | 6.1 | 5905 | 6050 |
| Milk, - - - - - - | 4146 | 26.8 | 38.7 | 29.2 | | 5.3 | 6205 | 6275 |
| Milk, - - - - - - | 4147 | 27.8 | 39.5 | 27.1 | | 5.6 | 6310 | 6635 |
| Milk, - - - - - - | 4148 | 27.9 | 34.0 | 32.1 | | 6.0 | 6010 | 6365 |
| Milk, - - - - - - | 4153 | 24.8 | 38.5 | 31.9 | | 4.8 | 6255 | 6565 |
| Milk, - - - - - - | 4154 | 24.0 | 41.8 | 29.1 | | 5.1 | 6400 | 6785 |
| Milk, - - - - - - | 4155 | 28.4 | 37.5 | 29.4 | | 4.7 | 6258 | 8378 |
| Milk, - - - - - - | 4156 | 26.6 | 40.4 | 27.4 | | 5.6 | 6341 | 6006 |
| Milk, - - - - - - | 4157 | 30.1 | 27.0 | 35.5 | | 7.4 | 5627 | 5850 |
| Average, - - - - - | — | **26.7** | **36.5** | **31.2** | | **5.6** | **6135** | **6500** |
| VEGETABLE FOODS. | | | | | | | | |
| Potatoes, boiled, - - - | 558 | 10.7 | .5 | 84.3 | | 4.5 | 4095 | 4115 |
| Potatoes, uncooked, - - | 559 | 11.6 | .7 | 83.8 | | 3.9 | 4140 | 4155 |

TABLE 45.—*(Continued.)*

| Food Materials. | Laboratory Number. | Protein. | Fat. | Carbohydrates. | | Ash. | Fuel Value per Gram. | |
|---|---|---|---|---|---|---|---|---|
| | | | | Fiber. | Nitrogen-free Extract. | | As Calculated. | As Determined. |
| | | % | % | % | % | % | Cal. | Cal. |
| Sweet potatoes, - - - | 556 | 2.8 | .9 | 93.8 | | 2.5 | 4085 | 4040 |
| Turnips, - - - - | 557 | 13.3 | 5.7 | 72.0 | | 9.0 | 4210 | 4125 |
| Squash, - - - - | 564 | 8.9 | 5.7 | 79.3 | | 6.1 | 4270 | 4200 |
| White beans, - - - | 548 | 27.0 | 2.1 | 67.0 | | 3.9 | 4430 | 4565 |
| Macaroni, - - - - | 544 | 16.2 | 1.0 | 81.9 | | .9 | 4345 | 4565 |
| Shredded cocoanut, - - | 546 | 6.7 | 66.6 | 25.2 | | 1.5 | 7595 | 7340 |
| Pearl tapioca, - - - | 547 | .3 | .2 | 99.1 | | .4 | 4100 | 4170 |
| Dates, - - - - | 587 | 2.8 | 6.5 | 88.8 | | 1.9 | 4395 | 4050 |
| Citron, - - - - | 588 | .6 | .8 | 97.4 | | 1.2 | 4100 | 3965 |
| Gelatine, - - - - | 589 | 94.5 | .4 | — | | 5.1 | 5235 | 5000 |
| Bread, quaker, - - - | 595 | 15.0 | 1.4 | 81.8 | | 1.8 | 4310 | 4460 |
| Bread, Saratoga, - - - | 596 | 16.4 | .6 | 80.9 | | 2.1 | 4275 | 4405 |
| Bread, home-made, - - | 597 | 14.7 | .6 | 82.9 | | 1.8 | 4265 | 4390 |
| Bread, domestic, - - - | 598 | 15.7 | .9 | 81.4 | | 2.0 | 4285 | 4415 |
| Bread, cream, - - - | 592 | 21.7 | 1.0 | 75.0 | | 2.3 | 4365 | 4425 |
| Bread, potato, - - - | 600 | 15.6 | .6 | 81.9 | | 1.9 | 4270 | 4400 |
| Bread, cornmeal, - - | 594 | 15.3 | .6 | 82.1 | | 2.0 | 4265 | 4475 |
| Average, - - - - | — | **16.3** | **.8** | **80.9** | | **2.0** | **4290** | **4425** |
| *Milling Products.* | | | | | | | | |
| Wheat flour, - - - | 376 | 14.8 | .9 | 83.7 | | .6 | 4330 | 4375 |
| Wheat flour, - - - | 378 | 13.7 | .8 | 85.0 | | .5 | 4315 | 4340 |
| Wheat flour, - - - | 381 | 14.3 | 1.0 | 84.2 | | .5 | 4330 | 4355 |
| Wheat flour, - - - | 479 | 16.3 | 1.4 | 81.8 | | .5 | 4380 | 4345 |
| Wheat flour, - - - | 534 | 14.1 | 1.3 | 84.1 | | .5 | 4345 | 4400 |
| Wheat flour, - - - | 549 | 15.0 | 1.2 | 83.2 | | .6 | 4350 | 4440 |
| Wheat flour, - - - | 575 | 14.9 | 1.4 | 83.1 | | .6 | 4360 | 4380 |
| Wheat flour, - - - | 580 | 15.2 | 1.4 | 82.7 | | .7 | 4355 | 4705 |
| Wheat flour, - - - | 591 | 14.7 | 1.5 | 83.2 | | .6 | 4360 | 4425 |
| Wheat flour, - - - | 480 | 11.9 | 1.5 | 86.1 | | .5 | 4325 | 4345 |
| Wheat flour, - - - | 550 | 13.3 | 1.1 | 85.1 | | .5 | 4320 | 4510 |
| Wheat flour, - - - | 581 | 13.5 | 1.4 | 84.6 | | .5 | 4340 | 4715 |
| Average, - - - - | — | **14.3** | **1.2** | **83.9** | | **.6** | **4345** | **4445** |
| Entire wheat flour, - - | 382 | 16.2 | 2.4 | 80.2 | | 1.2 | 4400 | 4410 |
| Rye flour, - - - - | 377 | 10.0 | 1.2 | 88.0 | | .8 | 4270 | 4290 |
| Buckwheat flour, - - - | 592 | 7.3 | 1.2 | 90.8 | | .7 | 4235 | 4325 |
| Rolled oats, - - - | 533 | 16.5 | 9.6 | 71.8 | | 2.1 | 4740 | 4995 |
| Rolled oats, - - - | 551 | 19.5 | 7.7 | 70.8 | | 2.0 | 4695 | 4905 |
| Average, - - - - | — | **18.0** | **8.7** | **71.3** | | **2.0** | **4720** | **4950** |
| Quaker oats, - - - | 582 | 16.0 | 8.0 | 74.1 | | 1.9 | 4665 | 4910 |
| Wheat germ meal, - - | 583 | 12.9 | 2.5 | 83.5 | | 1.1 | 4365 | 4550 |
| Corn meal, - - - - | 545 | 9.6 | 1.8 | 88.0 | | .6 | 4300 | 4405 |
| Corn meal, - - - - | 1305 | 11.4 | 5.4 | 80.3 | 1.5 | 1.4 | 4485 | 4505 |
| Corn meal, - - - - | 1300 | 11.6 | 4.9 | 80.6 | 1.5 | 1.4 | 4460 | 4520 |

TABLE 45.—*(Continued.)*

| Food Materials. | Laboratory Number. | Protein. | Fat. | Carbohydrates. Fiber. | Carbohydrates. Nitrogen-free Extract. | Ash. | Fuel Value per Gram. As Calculated. | Fuel Value per Gram. As Determined. |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | Cal. | Cal. |
| Corn meal, - - - - - | 12699 | 9.7 | 4.0 | 82.4 | 2.6 | 1.3 | 4390 | 4400 |
| Average, - - - - - | — | **10.6** | **4.0** | **84.2** | | **1.2** | **4410** | **4460** |
| Oil meal, - - - - - | 14870 | 39.2 | 2.3 | 10.0 | 42.7 | 5.8 | 4530 | 4635 |
| Gluten meal, - - - | 1207 | 13.1 | 15.4 | 63.8 | 6.3 | 1.4 | 5025 | 5590 |
| Wheat bran, - - - | 1208 | 20.5 | 5.9 | 60.5 | 7.4 | 5.7 | 4460 | 4645 |
| Wheat bran, - - - | 1301 | 18.9 | 5.9 | 58.0 | 11.2 | 6.0 | 4430 | 4585 |
| Wheat bran, - - - | 1304 | 19.9 | 5.6 | 57.1 | 11.1 | 6.3 | 4405 | 4585 |
| Wheat bran, - - - | 1306 | 18.4 | 5.7 | 59.2 | 10.3 | 6.4 | 4395 | 4555 |
| Wheat bran, - - - | 1338 | 18.1 | 5.6 | 58.3 | 11.3 | 6.7 | 4375 | 4530 |
| Average, - - - - - | — | **19.2** | **5.7** | **58.6** | **10.3** | **6.2** | **4415** | **4580** |
| *Mixed Grain.* | | | | | | | | |
| Linseed mixture,* - - | 1302 | 33.6 | 6.2 | 48.7 | 6.7 | 4.8 | 4690 | 4735 |
| Linseed mixture,* - - | 1339 | 33.1 | 6.1 | 49.1 | 6.9 | 4.8 | 4685 | 4750 |
| Average, - - - - - | — | **33.4** | **6.1** | **48.9** | **6.8** | **4.8** | **4690** | **4745** |
| Corn meal and cotton seed meal, | 11936 | 20.7 | 6.2 | 3.5 | 66.3 | 3.3 | 4575 | 4620 |
| Cob meal, - - - - - | 1209 | 9.6 | 5.4 | 81.6 | 1.8 | 1.6 | 4450 | 4545 |
| *Seeds.* | | | | | | | | |
| Oats and peas, ground, - | 1303 | 27.0 | 2.9 | 58.8 | 7.5 | 3.8 | 4470 | 4530 |
| Oats and peas, ground, - | 1340 | 25.1 | 2.8 | 59.8 | 8.6 | 3.7 | 4445 | 4515 |
| Average, - - - - - | — | **26.1** | **2.9** | **59.3** | **8.0** | **3.7** | **4460** | **4525** |
| Soy beans, - - - - - | 1363 | 40.2 | 18.1 | 30.6 | 5.0 | 6.1 | 5355 | 5495 |
| Soy beans, - - - - - | 1364 | 40.0 | 18.1 | 31.0 | 5.4 | 5.5 | 5375 | 5510 |
| Soy beans, - - - - - | 1365 | 42.5 | 18.2 | 29.4 | 4.5 | 5.4 | 5420 | 5535 |
| Average, - - - - - | — | **40.9** | **18.1** | **30.3** | **5.0** | **5.7** | **5385** | **5515** |
| *Hays.* | | | | | | | | |
| Timothy, - - - - - | 1006 | 9.1 | 3.8 | 46.9 | 33.0 | 7.2 | 4450 | 4810 |
| Timothy, - - - - - | 1007 | 10.4 | 3.6 | 48.1 | 31.1 | 6.8 | 4460 | 4850 |
| Timothy, - - - - - | 1355 | 11.6 | 3.2 | 43.4 | 36.2 | 5.6 | 4195 | 4595 |
| Timothy, - - - - - | 1356 | 6.8 | 2.7 | 52.5 | 31.7 | 6.3 | 4075 | 4515 |
| Timothy, - - - - - | 1357 | 19.5 | 3.2 | 33.7 | 37.9 | 5.7 | 4305 | 4530 |
| Timothy, - - - - - | 1358 | 7.8 | 3.6 | 45.7 | 37.4 | 5.5 | 4170 | 4545 |
| Average, - - - - - | — | **10.9** | **3.3** | **45.1** | **34.5** | **6.2** | **4275** | **4640** |
| Rye grass, - - - - - | 1008 | 12.6 | 2.9 | 48.7 | 27.7 | 8.1 | 4455 | 4745 |
| Early cut hay, - - - - | 1325 | 12.0 | 4.0 | 44.2 | 34.1 | 5.7 | 4245 | 4515 |
| Early cut hay, - - - - | 1326 | 12.5 | 3.9 | 45.4 | 32.7 | 5.5 | 4255 | 4505 |
| Early cut hay, - - - - | 1327 | 12.1 | 3.9 | 42.9 | 35.3 | 5.8 | 4235 | 4520 |
| Early cut hay, - - - - | 1328 | 12.2 | 3.8 | 44.9 | 33.3 | 5.8 | 4230 | 4505 |
| Average, - - - - - | — | **12.2** | **3.9** | **44.4** | **33.8** | **5.7** | **4240** | **4510** |
| Scarlet clover, - - - - | 1341 | 19.6 | 5.0 | 39.4 | 25.5 | 10.5 | 4205 | 4370 |

*One part corn meal, 3 parts old process linseed meal.

TABLE 45.—*(Continued.)*

| Food Materials. | Laboratory Number. | Protein. | Fat. | Carbohydrates. Fiber. | Carbohydrates. Nitrogen-free Extract. | Ash. | Fuel Value per Gram. As Calculated. | Fuel Value per Gram. As Determined. |
|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | Cal. | Cal. |
| Scarlet clover, - - - - | 1342 | 16.9 | 4.1 | 43.2 | 27.1 | 8.7 | 4190 | 4425 |
| Scarlet clover, - - - - | 1343 | 18.7 | 4.7 | 39.6 | 27.0 | 10.0 | 4195 | 4355 |
| Scarlet clover, - - - - | 1344 | 12.5 | 4.4 | 32.3 | 37.9 | 12.9 | 3975 | 4505 |
| Scarlet clover, - - - - | 1345 | 12.5 | 5.2 | 33.1 | 36.0 | 13.2 | 4005 | 4610 |
| Scarlet clover, - - - - | 1346 | 12.6 | 4.3 | 33.6 | 37.0 | 12.5 | 3990 | 4550 |
| Scarlet clover, - - - - | 1418 | 16.4 | 2.1 | 36.7 | 36.3 | 8.5 | 4090 | 4375 |
| Average, - - - - | — | **15.6** | **4.3** | **36.8** | **32.4** | **10.9** | **4095** | **4455** |
| Tall meadow oat grass, - | 1347 | 8.0 | 3.0 | 45.0 | 36.7 | 7.3 | 4070 | 4475 |
| Tall meadow oat grass, - | 1348 | 7.6 | 3.2 | 44.1 | 37.4 | 7.7 | 4055 | 4495 |
| Tall meadow oat grass, - | 1349 | 8.7 | 3.2 | 45.5 | 35.9 | 6.7 | 4115 | 4520 |
| Tall meadow oat grass, - | 1350 | 11.5 | 3.4 | 42.6 | 35.7 | 6.8 | 4155 | 4625 |
| Average, - - - - | — | **9.0** | **3.2** | **44.3** | **36.4** | **7.1** | **4100** | **4530** |
| Tall meadow fescue grass, - | 1351 | 6.0 | 2.4 | 40.2 | 44.4 | 7.0 | 4020 | 4395 |
| Tall meadow fescue grass, - | 1352 | 6.0 | 2.4 | 50.3 | 34.1 | 7.2 | 4010 | 4110 |
| Tall meadow fescue grass, - | 1353 | 6.9 | 2.7 | 45.9 | 37.1 | 7.4 | 4035 | 4395 |
| Tall meadow fescue grass, - | 1354 | 9.6 | 3.1 | 39.7 | 39.1 | 8.5 | 4045 | 4655 |
| Average, - - - - | — | **7.1** | **2.7** | **44.0** | **38.7** | **7.5** | **4030** | **4390** |
| Orchard grass, - - - - | 1359 | 7.6 | 3 0 | 44.6 | 37.0 | 7.8 | 4045 | 4370 |
| Orchard grass, - - - - | 1360 | 7.2 | 2.8 | 43.2 | 38.1 | 8.7 | 3995 | 4395 |
| Orchard grass, - - - - | 1361 | 7.9 | 3.5 | 43.7 | 36.3 | 8.6 | 4045 | 4365 |
| Orchard grass, - - - - | 1362 | 10.6 | 3.5 | 41.6 | 36.2 | 8.1 | 4095 | 4450 |
| Average, - - - - | — | **8.3** | **3.2** | **43.3** | **36.9** | **8.3** | **4045** | **4395** |
| Hay, - - - - - - | 8997 | 6.5 | 2.3 | 35.5 | 50.2 | 5.5 | 4085 | 4340 |
| Hay, - - - - - - | 8795 | 8.1 | 2.1 | 35.6 | 48.0 | 6.2 | 4070 | 4420 |
| Hay, - - - - - - | 12124 | 9.2 | 2.4 | 36.2 | 46.8 | 5.4 | 4130 | 4470 |
| Hay, - - - - - - | 12568 | 7.7 | 2.2 | 36.7 | 48.8 | 4.6 | 4135 | 4440 |
| Hay, - - - - - - | 14509 | 7.4 | 2.2 | 35.0 | 50.4 | 5.3 | 4115 | 4515 |
| Average, - - - - | — | **7.8** | **2.2** | **35.8** | **48.9** | **5.3** | **4105** | **4435** |
| Cow pea vines, - - - - | 1366 | 18.8 | 3.8 | 41.1 | 23.4 | 12.9 | 4035 | 4300 |
| Cow pea vines, - - - - | 1367 | 17.8 | 4.3 | 44.5 | 20.9 | 12.5 | 4060 | 4265 |
| Cow pea vines, - - - - | 1368 | 20.1 | 4.0 | 42.9 | 20.3 | 12.7 | 4070 | 4285 |
| Average, - - - - | — | **18.9** | **4.0** | **42.9** | **21.5** | **12.7** | **4055** | **4285** |
| Barley and pea fodder, - | 1369 | 20.9 | 4.4 | 40.2 | 25.7 | 8.8 | 4265 | 4555 |
| Barley and pea fodder, - | 1371 | 19.1 | 4.0 | 41.2 | 26.3 | 9.4 | 4190 | 4520 |
| Barley and pea fodder, - | 1373 | 20.7 | 4.8 | 42.4 | 24.3 | 7.8 | 4320 | 4615 |
| Barley and pea fodder, - | 1375 | 19.4 | 3.5 | 43.4 | 26.0 | 7.7 | 4240 | 4720 |
| Average, - - - - | — | **20.0** | **4.2** | **41.8** | **25.6** | **8.4** | **4255** | **4605** |
| Barley fodder, - - - - | 1370 | 16.1 | 3.9 | 44.7 | 26.6 | 8.7 | 4175 | 4525 |
| Barley fodder, - - - - | 1372 | 15.3 | 3.9 | 39.1 | 32.1 | 9.6 | 4120 | 4495 |
| Barley fodder, - - - - | 1374 | 15.7 | 3.9 | 44.0 | 27.2 | 9.2 | 4145 | 4545 |
| Barley fodder, - - - - | 1376 | 14.2 | 3.7 | 48.4 | 26.4 | 7.3 | 4190 | 4630 |
| Average, - - - - | — | **15.3** | **3.9** | **44.0** | **28.1** | **8.7** | **4160** | **4550** |
| Corn fodder, - - - - | 12125 | 7.9 | 2.1 | 27.7 | 56.2 | 6.1 | 4070 | 4325 |
| Corn ensilage. - - - - | 1377 | 7.5 | 3.6 | 57.3 | 25.0 | 6.6 | 4115 | 4515 |
| Rowen, - - - - - | 1399 | 16.2 | 5.3 | 39.9 | 30.5 | 8.1 | 4270 | 4650 |
| Rowen, - - - - - | 1400 | 17.2 | 5.3 | 41.7 | 28.3 | 7.5 | 4310 | 4675 |
| Average, - - - - | — | **16.7** | **5.3** | **40.8** | **29.4** | **7.8** | **4290** | **4665** |

TABLE 45.—(*Continued.*)

| FOOD MATERIALS. | Laboratory Number. | Protein. | Fat. | CARBOHYDRATES. Fiber. | CARBOHYDRATES. Nitrogen-free Extract. | Ash. | FUEL VALUE PER GRAM. As Calculated. | FUEL VALUE PER GRAM. As Determined. |
|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | Cal. | Cal. |
| *Feces.* | | | | | | | | |
| Man, | 572 | 42.3 | 24.5 | 18.6 | | 14.6 | 5365 | 6070 |
| Man, | 573 | 24.3 | 9.0 | 44.1 | | 22.6 | 3980 | 6005 |
| Man, | 574 | 21.9 | 14.9 | 38.4 | | 24.8 | 4165 | 6030 |
| Man, | 585 | 46.5 | 14.6 | 23.6 | | 15.3 | 4880 | 5600 |
| Average, | — | **33.8** | **15.7** | **31.2** | | 19.3 | **4600** | **5925** |
| Sheep, | 1307 | 16.6 | 4.6 | 26.4 | 42.5 | 9.9 | 4165 | 4700 |
| Sheep, | 1308 | 15.5 | 4.1 | 25.0 | 45.6 | 9.8 | 4125 | 4680 |
| Sheep, | 1309 | 16.2 | 4.5 | 26.4 | 41.3 | 11.6 | 4090 | 4665 |
| Sheep, | 1310 | 18.1 | 3.7 | 25.9 | 40.6 | 11.7 | 4065 | 4625 |
| Sheep, | 1311 | 15.8 | 4.2 | 25.7 | 42.7 | 11.6 | 4065 | 4585 |
| Sheep, | 1312 | 16.5 | 3.3 | 26.8 | 40.6 | 12.8 | 3980 | 4520 |
| Sheep, | 1313 | 18.5 | 5.0 | 25.7 | 40.9 | 9.9 | 4215 | 4780 |
| Sheep, | 1314 | 18.8 | 4.1 | 26.2 | 41.2 | 9.7 | 4180 | 4735 |
| Sheep, | 1383 | 12.0 | 3.7 | 39.4 | 32.7 | 12.2 | 3960 | 4650 |
| Sheep, | 1384 | 14.6 | 4.6 | 36.2 | 32.7 | 11.9 | 4060 | 4710 |
| Sheep, | 1385 | 10.8 | 4.5 | 35.8 | 38.9 | 10.0 | 4075 | 4730 |
| Sheep, | 1386 | 12.4 | 4.8 | 31.2 | 39.7 | 11.9 | 4035 | 4705 |
| Sheep, | 1395 | 15.0 | 7.6 | 28.0 | 39.4 | 10.0 | 4295 | 5040 |
| Sheep, | 1396 | 14.9 | 7.8 | 26.0 | 41.1 | 10.2 | 4300 | 5070 |
| Sheep, | 1397 | 14.0 | 7.8 | 26.3 | 42.8 | 9.1 | 4330 | 5070 |
| Sheep, | 1398 | 15.7 | 8.3 | 25.9 | 39.8 | 10.3 | 4330 | 5160 |
| Sheep, | 1401 | 14.9 | 7.1 | 28.9 | 38.2 | 10.9 | 4230 | 4995 |
| Sheep, | 1402 | 13.4 | 7.5 | 31.3 | 42.2 | 5.6 | 4445 | 4980 |
| Sheep, | 1403 | 14.1 | 7.3 | 28.7 | 39.6 | 10.3 | 4255 | 5010 |
| Sheep, | 1404 | 15.4 | 7.9 | 23.8 | 40.4 | 12.5 | 4215 | 5005 |
| Sheep, | 1419 | 11.1 | 2.2 | 46.1 | 31.4 | 9.2 | 3995 | 4565 |
| Sheep, | 1420 | 11.4 | 2.3 | 46.0 | 29.6 | 10.7 | 3940 | 4560 |
| Sheep, | 1421 | 11.2 | 2.4 | 42.5 | 34.1 | 9.8 | 3980 | 4535 |
| Sheep, | 1422 | 11.7 | 2.2 | 43.7 | 32.9 | 9.5 | 3990 | 4585 |
| Sheep, | 9292 | 8.0 | 2.6 | 41.0 | 40.6 | 7.8 | 4030 | 4630 |
| Sheep, | 9293 | 7.8 | 2.5 | 41.0 | 41.0 | 7.7 | 4025 | 4610 |
| Sheep, | 9294 | 7.3 | 2.3 | 43.2 | 40.3 | 6.9 | 4040 | 4615 |
| Sheep, | 10145 | 8.2 | 2.4 | 40.9 | 41.7 | 6.8 | 4065 | 4800 |
| Sheep, | 10146 | 8.6 | 2.4 | 41.3 | 40.1 | 7.6 | 4030 | 4705 |
| Sheep, | 10147 | 7.9 | 2.3 | 39.5 | 43.5 | 6.8 | 4050 | 4700 |
| Sheep, | 12803 | 7.6 | 2.2 | 49.5 | 34.7 | 6.0 | 4075 | 4765 |
| Sheep, | 12804 | 8.0 | 2.3 | 45.6 | 37.8 | 6.3 | 4075 | 4700 |
| Sheep, | 12126 | 13.8 | 2.4 | 33.8 | 40.1 | 9.9 | 4010 | 4615 |
| Sheep, | 12127 | 13.7 | 2.5 | 29.7 | 44.5 | 9.6 | 4030 | 4620 |
| Sheep, | 12128 | 12.7 | 2.1 | 41.3 | 34.7 | 9.2 | 4010 | 4565 |
| Sheep, | 12562 | 16.4 | 3.0 | 32.0 | 39.7 | 8.9 | 4120 | 4675 |
| Sheep, | 12563 | 17.9 | 2.4 | 24.2 | 45.8 | 9.7 | 4080 | 4580 |
| Sheep, | 12564 | 14.8 | 2.0 | 28.5 | 45.5 | 9.2 | 4035 | 4560 |
| Sheep, | 14958 | 8.8 | 1.7 | 45.9 | 36.8 | 6.8 | 4035 | 4725 |
| Sheep, | 14959 | 9.9 | 1.7 | 44.0 | 37.8 | 6.6 | 4055 | 4810 |
| Sheep, | 14960 | 9.6 | 1.5 | 41.8 | 40.5 | 6.6 | 4440 | 4655 |
| Average, | — | **12.9** | **3.9** | **34.4** | **39.4** | **9.4** | **4110** | **4730** |

## METEOROLOGICAL OBSERVATIONS.

BY C. S. PHELPS.

The meteorological observations made at the Storrs Station during 1894 have been similar to those of past years. The Station equipment consists of the ordinary instruments for obtaining temperature, pressure of the air, humidity, rainfall and snowfall, uniform with those used by voluntary observers for the U. S. Weather Service. In addition to the records made at Storrs, the rainfall for the growing season has been recorded by farmers conducting field experiments for the Station, and a few other voluntary observers.

The total precipitation for the year (33.3 inches), as measured at the Station, was far below the average. The average annual precipitation for six Connecticut stations of the New England Meteorological Society, having records covering a period of ten or more years prior to 1890, is 49.1 inches. The average at Storrs for five years ending with 1893 is 46.8 inches, and including 1894 the average for six years is 44.5 inches. The monthly precipitation was least during the growing season (May–November). In many places the drouth became unusually severe during June and July, so that the hay and grain crops suffered considerably.

The temperature for January was a little above the average, while February was three degrees below the average, and March several degrees above. The spring opened later than usual. The last severe frost occurred May 15th, doing considerable damage to early vegetables. The summer was quite hot and dry with light rainfalls till September. Very light frost appeared on low ground September 12th, and the first killing frost occurred September 26th. This gave a growing season of 134 days since the last killing frost in the spring, while the average growing season since the Station began observations in 1888 is 143 days. The temperature for September and October was above the

average, and the conditions were favorable for harvesting most crops. Heavy snow came unusually early (November 6th), and many farmers had turnips and celery badly frosted.

Through the kindness of the New England Meteorological Society we are able to publish the rainfall records from sixteen of their Stations.

Table 46 gives the rainfall as recorded for the six months ending October 31st for twenty-three localities in the State, and table 47 gives the summary of observations made by the Station at Storrs.

TABLE 46.

*Rainfall During the Six Months Ending October 31, 1894.*

| Locality. | Observer. | Inches Per Month. May. | June. | July. | August. | September. | October. | Total. |
|---|---|---|---|---|---|---|---|---|
| Falls Village, | M. H. Dean, | — | .86 | 1.35 | .57 | 4.44 | 4.06 | — |
| Norwalk, | G. C. Comstock,* | 4.88 | 1.49 | .83 | 1.23 | 5.52 | 5.86 | 19.81 |
| Greenfield Hill, | Sanford Jennings,* | 6.15 | .87 | .70 | 1.64 | 4.68 | 5.61 | 19.65 |
| Bridgeport, | William Jennings,* | 6.12 | 1.38 | .69 | 2.29 | 5.86 | 7.25 | 23.59 |
| Waterbury, | N. J. Welton,* | 7.58 | .54 | 2.43 | 2.41 | 5.35 | 4.91 | 23.22 |
| New Hartford, | R. R. Smith,* | 5.48 | 1.77 | 3.71 | 1.29 | 5.64 | 6.46 | 24.35 |
| Canton, | G. J. Case,* | 5.58 | .58 | 1.92 | .73 | 5.58 | 6.46 | 20.85 |
| West Simsbury, | S. T. Stockwell,* | 5.47 | .59 | 1.95 | .75 | 5.71 | 6.34 | 20.81 |
| Southington, | Lumen Andrews,* | 6.85 | .65 | 2.00 | 2.15 | 5.60 | 6.30 | 23.55 |
| New Haven, | Weather Bureau,* | 4.49 | .49 | 2.40 | 1.70 | 4.63 | 6.11 | 19.81 |
| Wallingford, | Mrs. B. F. Harrington,* | 4.56 | .65 | 1.16 | 2.23 | 4.88 | 7.07 | 20.55 |
| Hartford, | Prof. S. Hart,* | 5.63 | .31 | 1.44 | 2.44 | 5.82 | 6.50 | 22.14 |
| South Manchester, | K. B. Loomis, | 5.26 | .66 | 1.70 | 2.84 | 2.37 | 5.42 | 18.25 |
| Middletown, | C. W. Hubbard,* | 5.29 | .39 | 1.10 | 1.33 | 3.55 | 8.00 | 19.66 |
| Madison, | J. D. Kelsey, | — | — | 1.17 | 2.76 | 3.71 | 8.29 | — |
| Lake Konomoc, | New London W. W'ks,* | 3.91 | .64 | .93 | 1.35 | 2.09 | 6.77 | 15.69 |
| New London, | Weather Bureau,* | 3.53 | .53 | .44 | 2.91 | 2.59 | 7.21 | 17.21 |
| Colchester, | S. P. Willard,* | 4.03 | .49 | 2.05 | 1.07 | 3.01 | 5.83 | 16.48 |
| Lebanon, | E. A. Hoxie, | 4.11 | .66 | 2.06 | 1.73 | 2.48 | 5.96 | 17.00 |
| Lebanon, | J. H. Tucker, | 4.63 | 1.08 | 1.35 | 1.51 | — | 5.75 | — |
| Storrs, | Experiment Station, | 3.58 | .59 | 2.09 | 2.37 | 3.01 | 4.16 | 15.80 |
| Ekonk, | George H. Gallup, | — | .55 | .41 | 2.15 | 2.63 | — | — |
| Voluntown, | Rev. C. Dewhurst,* | 4.25 | 1.42 | 1.83 | 2.22 | 2.30 | 5.64 | 17.66 |
| Average, | - - - - - - | **5.07** | **.75** | **1.55** | **1.81** | **4.15** | **6.18** | **19.79** |

* New England Meteorological Society Observer.

TABLE 47.

*Meteorological Summary for 1894.*

OBSERVATIONS MADE AT STORRS BY THE STATION.

| | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Mean. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Highest barometer, - - - | 30.74 | 30.84 | 30.50 | 30.48 | 30.42 | 30.30 | 30.27 | 30.19 | 30.54 | 30.41 | 30.65 | 30.49 | 30.44 | — |
| Lowest barometer, - - - | 28.92 | 29.23 | 29.57 | 29.66 | 29.58 | 29.58 | 29.72 | 29.81 | 29.71 | 29.20 | 29.42 | 29.39 | 29.48 | — |
| Mean barometer, - - - | 30.14 | 30.13 | 30.07 | 30.03 | 29.98 | 29.98 | 29.98 | 30.03 | 30.12 | 29.99 | 30.07 | 30.01 | 30.04 | — |
| Highest temperature, - - | 54.8 | 47.0 | 64.5 | 74.0 | 85.0 | 90.0 | 95.0 | 83.8 | 86.0 | 22.5 | 63.7 | 52.0 | 72.3 | — |
| Lowest temperature, - - - | 2.0 | −11.5 | 14.0 | 14.8 | 37.0 | 41.0 | 47.5 | 43.0 | 38.8 | 32.9 | 8.5 | 2.2 | 22 5 | — |
| Mean temperature, - - - | 27.7 | 23.0 | 38.6 | 44.7 | 56.4 | 66.0 | 70.9 | 65.8 | 63.0 | 50.6 | 34.1 | 28.2 | 47.4 | — |
| Relative humidity, - - - | — | — | — | 65.6 | 69.6 | 72.8 | 71.6 | 74.3 | 70.6 | 73.3 | — | — | 71.1 | — |
| Total precipitation, - - - | 2.24 | 3.13 | 1.18 | 2.67 | 3.58 | .59 | 2.09 | 2.37 | 3.01 | 4.16 | 4.00 | 4.31 | — | 33.33 |
| Number of days with precipitation of .01 inch or more, | 12 | 11 | 9 | 8 | 8 | 7 | 10 | 5 | 9 | 9 | 11 | 9 | — | 108 |
| Number of clear days, - - | 9 | 6 | 7 | 8 | 8 | 7 | 10 | 8 | 7 | 11 | 14 | 11 | — | 106 |
| Number of fair days, - - | 11 | 12 | 15 | 9 | 10 | 10 | 17 | 15 | 15 | 10 | 7 | 11 | — | 142 |
| Number of cloudy days, - - | 11 | 10 | 9 | 13 | 13 | 13 | 4 | 8 | 8 | 10 | 9 | 9 | — | 117 |

# COÖPERATIVE FIELD EXPERIMENTS WITH FERTILIZERS.

BY C. S. PHELPS.

The field experiments conducted by the Station at Storrs and in different parts of the State have been mainly "soil tests." Owing to the severe drouth which was so generally unfavorable to farm crops during July and August, most of these experiments were more or less injured. At best the deductions from any one experiment are mainly applicable only to the particular soil upon which the experiment was made and, to some extent, to similar soils in the immediate locality. When a large number of experiments, covering a great variety of soils in different localities are studied, some general deductions may be made. This has been done in Bulletin 10 and in the Fifth Annual Report, 1892, of this Station. The great number of soil test experiments there compiled show that heavy, clayey soils, in Connecticut, are generally lacking in phosphoric acid, while the lighter, more sandy soils show, in general, a lack of potash.

The object aimed at in these experiments has been to study the soils of different regions of the State and learn their deficiencies, and thus to help the owners to find how to apply fertilizers so as to meet the needs of particular soils and crops in an economical manner. In many cases where experiments have been made we find farmers as well able to look after the details of the work as a representative of the Station. As the Station has taken up so many other lines of work it has been thought best not to continue "soil tests" as a regular branch of our work, but as far as individual farmers wish to test their own soil, to give instruction and advice.

The following persons and organizations have coöperated in this class of experiments during the past year:

| | POST OFFICE. |
|---|---|
| J. M. Hull, | Madison. |
| J. D. Kelsey, | Madison. |
| E. K. Clauss, | Rockville. |
| Ekonk Grange, | Ekonk. |
| The Station, | Storrs. |

We are glad to announce that one Grange in the State, which owns a small farm, has invited the Station to aid it in conducting a series of field experiments.

In connection with most of the experiments rainfall records have been kept during the growing season. These, with the records from quite a number of other localities in the State, will be found on page 159 of this Report. From these records it will be seen that during that part of the season (June, July and August) when the corn crop most needs moisture the rainfall was very deficient.

### POUNDS REQUIRED FOR A BUSHEL OF DRY SHELLED CORN.

The percentages of water at harvest in the corn of the different experiments are found to vary considerably. The field weights are not an accurate measure of the value of the crop. The moisture and the proportions of cob to corn vary widely on different fields, but have been found to be fairly uniform on different plots of the same field. Moisture tests of the corn, at the time of harvest, have been made for all but one of the experiments in order to find the number of pounds of ears required to make a bushel of dry shelled corn. The differences in the percentages of water-free corn may be ascribed to two causes; variations in the proportion of corn to cob and variations in the moisture contained in the ears at harvest.

TABLE 48.

*Percentages of Dry Matter of Corn in Ears (Grain and Cob) and the Number of Pounds of Ears Required for a Bushel of Shelled Corn.*

| NAME AND LOCALITY. | Water-free Corn in Samples (Ears) at Harvest. | | Pounds of Ears at Harvest to Equal 56 lbs. Shel'd Corn with 11 % Water. | |
|---|---|---|---|---|
| | Good. | Poor. | Good. | Poor. |
| | % | % | Lbs. | Lbs. |
| J. M. Hull, Madison, - - - | 68.4 | 61.1 | 73 | 81 |
| J. D. Kelsey, Madison, - - - | 61.6 | 55.3 | 81 | 90 |
| E. K. Clauss, Rockville, - - - | 70.0 | 62.7 | 71 | 79 |
| Ekonk Grange, Ekonk, - - - | 50.4 | 43.0 | 98 | 115 |
| Station, Storrs, - - - - - | 59.5 | 56.8 | 84 | 87 |

The differences seen in the table point out the importance of knowing the moisture in the crop of each field instead of depending upon averages. From 70 to 75 pounds are commonly

considered a sufficient weight of ears to make one bushel of dry shelled corn. In these experiments an average of 81 pounds was required for the good corn.

## SOIL TEST EXPERIMENTS.

The plan of experiments for soil tests consists in applying, on parallel plots of land, fertilizers containing nitrogen, phosphoric acid and potash, singly, two by two, and all three together. The fertilizing materials were in all cases supplied by the Station in standard commercial forms, such as nitrate of soda, dissolved bone-black, and muriate of potash. In all of the experiments here described, the cost of the fertilizer is estimated from the retail selling prices of the materials, plus $2 per ton for mixing and freight.

In most of the experiments a number of plots were added to the regular soil test. The object of these plots was to study the question of the most profitable mixture for use on particular soils.

On the following pages, the comparative yields of the experiments discussed are shown by means of diagrams. The fertilizers and the weights are given at the left of the diagram. The length of the lines represent the comparative yields per acre from the different plots, and the figures given in the last column show the actual yields per acre.

At the close of this article will be found a series of tabular statements, giving the results in detail. In all cases, the yield of shelled corn per acre is reported on the basis of 11 per cent. water, and the stover on the basis of field weights.

## EXPERIMENT BY E. K. CLAUSS.

The field upon which this experiment was located had been in grass for quite a period of years and was considerably "run down" by constant cropping without manures. One end of plots I and K extended onto ground that had been planted to potatoes the year before, and this may account in part for the small yields on those plots. The soil is a medium heavy loam with a gravelly clay subsoil. From the diagram it will be seen that the plots to which phosphoric acid (from dissolved bone-black) was applied, gave better yields than those where no phosphoric acid was used. This is in accord with many other experiments on similar soils.

## SOIL TEST WITH FERTILIZERS ON CORN.

By E. K. CLAUSS, Rockville.

| No. of Plot. | Fertilizer. Kind. | Fertilizer. Lbs. per Acre. | Yield Shelled Corn Per Acre. (11 % Water.) Comparative Scale. | Bu. |
|---|---|---|---|---|
| 0, | Nothing, - - | — | | 38.2 |
| A, | Nitrate of Soda, - | 160 | | 37.6 |
| B, | Dis. Bone-black, - | 320 | | 45.4 |
| C, | Muriate of Potash, | 160 | | 41.6 |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | | 47.1 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, | 160<br>160 | | 40.4 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, | 320<br>160 | | 47.9 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, | 160<br>320<br>160 | | 51.2 |
| 00, | Nothing, - - | — | | 42.8 |
| H, | Nitrate of Soda, -<br>Ammonite, - -<br>Muriate of Potash,<br>S.C. Dis. R'k Phos., | 125<br>100<br>200<br>350 | | 50.7 |
| I, | P. Cooper's Bone,<br>Nitrate of Soda, -<br>Muriate of Potash, | 300<br>175<br>200 | | 46.3 |
| K, | Dry ground Fish, -<br>Muriate of Potash, | 510<br>200 | | 39.4 |

### EXPERIMENT BY J. M. HULL.

The field where this experiment was located had been in grass the previous year, and, owing to a poor "catch," gave but a small yield. The field was sown to oats in 1892 and seeded to grass with the oats. When plowed in the spring of 1894, preparatory to the experiment, there was a thin turf of grass and clover. The soil is a light loam with a sandy to gravelly subsoil. The field sloped somewhat toward the first nothing plot (0) and the yield on that plot was no doubt considerably increased by the more favorable moisture conditions there found. For this reason it has been thought best to use only one nothing plot (00) for calculating the gain on the other plots. Plot 00 seemed to represent much more nearly the average condition of the soil. The results on plot H are omitted because of an error in planting. The soil on plots F and G was somewhat more gravelly

than on the other plots, and the crop there seemed to suffer more from the effects of the drouth. Nitrogen (from nitrate of soda) seemed to give the greatest increase of crop in this experiment, although all three of the fertilizing ingredients appeared to be somewhat lacking in the soil.

## SOIL TEST WITH FERTILIZERS ON CORN.

By J. M. HULL, Madison.

| No. of Plot. | Fertilizer. | | Yield Shelled Corn Per Acre. (11 % Water.) | |
|---|---|---|---|---|
| | Kind. | Lbs. per Acre. | Comparative Scale. | Bu. |
| 0, | Nothing, - - | — | | 49.7 |
| A, | Nitrate of Soda, - | 160 | | 52.4 |
| B, | Dis. Bone-black, - | 320 | | 51.7 |
| C, | Muriate of Potash, | 160 | | 50.4 |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | | 61.1 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, | 160<br>160 | | 54.0 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, | 320<br>160 | | 42.8 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, | 160<br>320<br>160 | | 40.9 |
| 00, | Nothing, - - | — | | 39.8 |
| H, | Nitrate of Soda, -<br>Ammonite, - -<br>Muriate of Potash,<br>S.C. Dis. R'k Phos., | 125<br>100<br>200<br>350 | | — |
| I, | P. Cooper's Bone, -<br>Nitrate of Soda, -<br>Muriate of Potash, | 300<br>175<br>200 | | 52.4 |
| K, | Dry ground Fish, -<br>Muriate of Potash, | 510<br>200 | | 41.5 |

### EXPERIMENT BY J. D. KELSEY.

The experiment by Mr. Kelsey was on a light loam soil with a sandy to gravelly subsoil. Rye was grown on the field in 1893, and at the same time the field was seeded to grass but failed to "catch." The soil of the field was quite uneven in texture and the drouth affected the plots unequally.

On the whole nitrogen gave the most striking results. Phosphoric acid and potash alone gave no increase over the nothing plot near by, although the nitrate of soda (A) plot gave an increase of 10.5 bushels over the nothing plot adjoining.

## SOIL TEST WITH FERTILIZERS ON CORN.

By J. D. KELSEY, Madison.

| No. of Plot. | Fertilizer. Kind. | Fertilizer. Lbs. per Acre. | Yield Shelled Corn Per Acre. (11 % Water.) Comparative Scale. | Yield Shelled Corn Per Acre. (11 % Water.) Bu. |
|---|---|---|---|---|
| o, | Nothing, - - | — | | 45.4 |
| A, | Nitrate of Soda, - | 160 | | 55.9 |
| B, | Dis. Bone-black, - | 320 | | 42.2 |
| C, | Muriate of Potash, | 160 | | 43.2 |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | | 55.2 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, | 160<br>160 | | 58.7 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, | 320<br>160 | | 51.6 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, | 160<br>320<br>160 | | 45.0 |
| oo, | Nothing, - - | — | | 41.6 |
| H, | Nitrate of Soda, -<br>Ammonite, - -<br>Muriate of Potash,<br>S. C. Dis. R'k Phos., | 125<br>100<br>200<br>350 | | 51.7 |
| I, | P. Cooper's Bone,<br>Nitrate of Soda, -<br>Muriate of Potash, | 300<br>175<br>200 | | 52.0 |
| K, | Dry ground Fish, -<br>Muriate of Potash, | 510<br>200 | | 55.4 |

### EXPERIMENT BY EKONK GRANGE.

In February, 1894, a representative of this Grange opened correspondence with the Station, stating that the Grange desired to undertake coöperative experiments running through a period of years. The committee from the Grange consisted of George H. Gallup and A. A. Stanton, of Ekonk, and John A. Tanner, of Campbell's Mills.

The soil of the field was a heavy clay loam with clay subsoil. The field had been in grass for a period of years without fertilizers and produced but small crops.

The experiment planned for 1894 was a soil test on corn with five additional plots designed to study the best and most economical mixture of fertilizer for the soil under the experiment, and similar soils in that vicinity. Plots I and K were supplied with uniform quantities of fertilizing ingredients, but on I the nitrogen

was added as nitrate of soda, and on K as organic nitrogen from animal flesh (ammonite). The yields in the two cases were essentially the same. Of the complete fertilizers, the most economical mixture was that used on plot M, costing $13.00 per acre. The mixture supplied nitrogen and potash in the same proportion as the other complete fertilizers, but furnished phosphoric acid in quite large quantities (85 lbs. per acre). The results of the soil test part of the experiment, as far as showing the deficiencies of the soil is concerned, are not conclusive. A repetition of the work, under more favorable conditions of weather, is needed before conclusions can be drawn.

### SOIL TEST WITH FERTILIZERS ON CORN.

By EKONK GRANGE, Ekonk.

| No. of Plot. | Fertilizer. | | Yield Shelled Corn Per Acre. (11 % Water.) | |
|---|---|---|---|---|
| | Kind. | Lbs. per Acre. | Comparative Scale. | Bu. |
| 0, | Nothing, - - | — | | 21.2 |
| A, | Nitrate of Soda, - | 160 | | 22.4 |
| B, | Dis. Bone-black, - | 320 | | 21.8 |
| C, | Muriate of Potash, | 160 | | 30.8 |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | | 27.3 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, | 160<br>160 | | 28.9 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, | 320<br>160 | | 41.5 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, | 160<br>320<br>160 | | 40.2 |
| 00, | Nothing, - - | — | | 23.4 |
| H, | Ashes, - - - | 1000 | | 35.1 |
| I, | Nitrate of Soda, -<br>Muriate of Potash,<br>Dis. Bone-black, - | 160<br>160<br>480 | | 43.8 |
| K, | Ammonite, - -<br>Muriate of Potash,<br>Dis. Bone-black, - | 190<br>160<br>480 | | 44.2 |
| L, | P. Cooper's Bone, -<br>Nitrate of Soda, -<br>Muriate of Potash, | 500<br>100<br>160 | | 41.1 |
| M, | Nitrate of Soda, -<br>Ammonite, - -<br>Muriate of Potash,<br>S. C. Dis. R'k Phos., | 90<br>80<br>160<br>600 | | 45.2 |
| 000 | Nothing, - - | — | | 28.5 |

### EXPERIMENT BY THE STATION.

This experiment is the fifth in a series planned as a rotation soil test experiment, the same fertilizers being used on the same plots year after year.* Beginning with 1890 the crops grown on this field have been corn, potatoes, oats, cow peas and corn.

The field slopes gently to the south, but not enough to cause serious washing. The soil is a heavy loam, and the subsoil is a yellow, clay loam. In 1889 it was noticed that the soil seemed to be poorer toward the west side of the field. For this reason the field was laid out into two half-acre experiments, the order of the plots on the two being reversed, as per diagram.

ARRANGEMENT OF PLOTS IN STATION EXPERIMENT.

UNMANURED STRIPS SEPARATE THE PLOTS.

EAST.

| NORTH. | | | SOUTH. |
|---|---|---|---|
| | Plot o. | Plot Y. | |
| | Plot A. | Plot X. | |
| | Plot B. | Plot ooo. | |
| | Plot C. | Plot G. | |
| | Plot oo. | Plot F. | |
| | Plot D. | Plot E. | |
| | Plot E. | Plot D. | |
| | Plot F. | Plot oo. | |
| | Plot G. | Plot C. | |
| | Plot ooo. | Plot B. | |
| | Plot X. | Plot A. | |
| | Plot Y. | Plot o. | |

WEST.

The yields of the duplicate plots in each case are averaged in estimating the yield per acre. This helps to eliminate the errors due to irregularities of soil. Beside the regular soil test, two other plots were added—one (X) with a medium amount (12,000 pounds) of manure, and in addition dissolved bone-black at the rate of 160 pounds per acre; the other (Y) with a larger quantity (16,000 pounds) of stable manure, but without bone-black.

In 1890 a soil test with corn (the first of the series) was made upon these same plots with the following results, which are

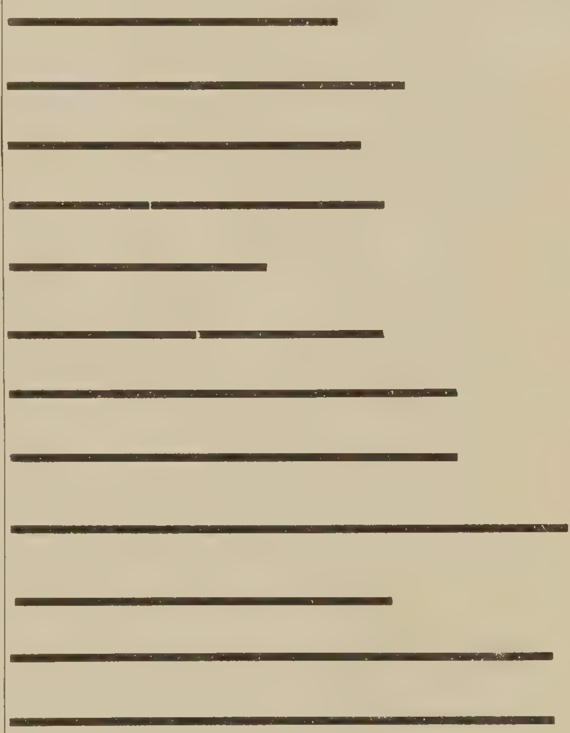
* For description and results of earlier experiments on this field, see Report of this Station, 1890, pp. 69–71.

quoted from the Annual Report for 1891: "The results show that phosphoric acid had the most marked effect, nitrogen considerable, while potash gave but little increase over nothing. There is no very great increase from the use of any of the ingredients, and it seems probable that the soil was supplied with accumulated stores of fertility which the two years' cropping had not entirely exhausted."

SOIL TEST WITH FERTILIZERS ON CORN, 1894.

By THE STATION, Storrs.

| No. of Plot. | Fertilizer. | | Yield Shelled Corn Per Acre. (11 % Water.) | |
|---|---|---|---|---|
| | Kind. | Lbs. per Acre. | Comparative Scale. | Bu. |
| 0, | Nothing, - - | — | | 33.6 |
| A, | Nitrate of Soda, | 160 | | 41.0 |
| B, | Dis. Bone-black, | 320 | | 37.6 |
| C, | Mur. of Potash, | 160 | | 40.8 |
| 00, | Nothing, - - | — | | 28.0 |
| D, | Nitrate of Soda,<br>Dis. Bone-black, | 160<br>320 | | 40.8 |
| E, | Nitrate of Soda,<br>Mur. of Potash, | 160<br>160 | | 47.6 |
| F, | Dis. Bone-black,<br>Mur. of Potash, | 320<br>160 | | 48.2 |
| G, | Nitrate of Soda,<br>Dis. Bone-black,<br>Mur. of Potash, | 160<br>320<br>160 | | 58.2 |
| 000 | Nothing, - - | — | | 38.9 |
| X, | Stable Manure, -<br>Dis. Bone-black, | 12000<br>160 | | 57.0 |
| Y, | Stable Manure, - | 16000 | | 56.7 |



The results for the past season show that all of the fertilizing ingredients were needed to produce good crops, but that potash was most essential, while in 1892, with oats, the nitrogen had the most marked influence. This illustrates the importance of modifying the fertilizer in accordance with the demand of the crop as well as the peculiarities of the soil.

*Yields on Station Soil Test Experiment for past Five Years.*

| No. of Plot. | Fertilizer. | Lbs. per Acre. | Corn. 1890. | Potato's 1891. | Oats. 1892. | Cow Peas (vines). 1893. | Corn. 1894. |
|---|---|---|---|---|---|---|---|
| | *Kind.* | | Bu. | Bu. | Bu. | Lbs. | Bu. |
| 0, | Nothing, - - - - | — | 28.9 | 89 | 29.1 | 10,230 | 33.6 |
| A, | Nitrate of Soda, - - | 160 | 32.4 | 105 | 36.0 | 10,960 | 41.0 |
| B, | Dis. Bone-black, - - | 320 | 33.3 | 97 | 27.0 | 10,710 | 37.6 |
| C, | Muriate of Potash, - | 160 | 30.4 | 171 | 26.3 | 11,680 | 40.8 |
| 00, | Nothing, - - - - | — | 26.7 | 87 | 24.2 | 9,725 | 28.0 |
| D, | Nitrate of Soda, - -<br>Dis. Bone-black, - - | 160<br>320 | 36.1 | 110 | 37.9 | 12,920 | 40.8 |
| E, | Nitrate of Soda, - -<br>Muriate of Potash, - | 160<br>160 | 32.8 | 160 | 30.0 | 13,335 | 47.6 |
| F, | Dis. Bone-black, - -<br>Muriate of Potash, - | 320<br>160 | 34.4 | 214 | 27.8 | 15,790 | 48.2 |
| G, | Nitrate of Soda, - -<br>Dis. Bone-black, - -<br>Muriate of Potash, - | 160<br>320<br>160 | 37.4 | 259 | 39.4 | 16,210 | 58.2 |
| 000, | Nothing, - - - - | — | 28.5 | 88 | 22.5 | 12,100 | 38.0 |
| X, | Stable Manure, - -<br>Dis. Bone-black, - - | 12000<br>160 | 44.1 | 210 | 40.9 | 15,795 | 57.0 |
| Y, | Stable Manure, - - | 16000 | 43.6 | 250 | 41.3 | 15,875 | 56.7 |

The larger yields obtained last year (1894) on corn as compared with the season of 1890 are probably due to fertilizing materials left over from the leguminous crop (cow peas) grown in 1893. The beneficial effects of the growing of legumes, on soil fertility, and their importance in a rotation can not be too strongly urged on our farmers.

For general conclusion with the class of experiments the reader is referred to Bulletin 10 and the Fifth Annual Report of this Station.

Our thanks are due to Mr. Francisco J. San Roman, Honorary Delegate of the Chilian Nitrate Combination to the Columbian Exposition, for the nitrate of soda used in the experiments here reported upon.

TABLE 49.—SOIL TEST WITH FERTILIZERS ON CORN.

| No. of Plot. | Fertilizers Per Acre. | | | Yield Per Plot 1-10 Acre. | | | Yield Per Acre. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kind. | Weight. | Cost. | Ears. Good. | Ears. Poor. | Stover. | Shel'd Corn (11 % water). Good. | Shel'd Corn (11 % water). Poor. | Stover. | Gain over Nothing Plots. |
| | *By E. K. Clauss, Rockville.* | Lbs. | $ | Lbs. | Lbs. | Lbs. | Bu. | Bu. | Lbs. | Bu. |
| 0, | Nothing, - - | — | — | 265 | 7 | 179 | 37.4 | .8 | 1790 | — |
| A, | Nitrate of Soda, - | 160 | 3.96 | 267 | — | 156 | 37.6 | — | 1560 | −2.9 |
| B, | Dis. Bone-black, - | 320 | 4.40 | 321 | 2 | 170 | 45.2 | .2 | 1700 | 4.9 |
| C, | Muriate of Potash, | 160 | 3.48 | 294 | 2 | 198 | 41.4 | .2 | 1980 | 1.1 |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | 8.48 | 330 | 6 | 208 | 46.4 | .7 | 2080 | 6.6 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, | 160<br>160 | 7.52 | 275 | 14 | 199 | 38.7 | 1.7 | 1990 | −.1 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, | 320<br>160 | 8.00 | 327 | 14 | 198 | 46.2 | 1.7 | 1980 | 7.4 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, | 160<br>320<br>160 | 12.00 | 350 | 16 | 212 | 49.2 | 2.0 | 2120 | 11.7 |
| 00, | Nothing, - - | — | — | 289 | 17 | 183 | 40.7 | 2.1 | 1830 | — |
| H, | Nitrate of Soda, -<br>Ammonite, - -<br>Muriate of Potash,<br>S.C.Dis.Rock Phos., | 125<br>100<br>200<br>350 | 13.03 | 350 | 12 | 273 | 49.2 | 1.5 | 2730 | 10.2 |
| I, | Peter Cooper's Bone,<br>Nitrate of Soda, -<br>Muriate of Potash, | 300<br>175<br>200 | 12.98 | 317 | 14 | 233 | 44.6 | 1.7 | 2330 | 5.8 |
| K, | Dry-ground Fish, -<br>Muriate of Potash, | 510<br>200 | 13.07 | 255 | 28 | 236 | 35.9 | 3.5 | 2360 | −1.1 |
| | *By J. M. Hull, Madison.* | | | | | | | | | |
| 0, | Nothing, - - | — | — | 349 | 16 | 231 | 47.8 | 1.9 | 2310 | — |
| A, | Nitrate of Soda, - | 160 | 3.96 | 367 | 18 | 271 | 50.2 | 2.2 | 2710 | 12.6 |
| B, | Dis. Bone-black, - | 320 | 4.40 | 364 | 16 | 265 | 49.8 | 1.9 | 2650 | 11.9 |
| C, | Muriate of Potash, - | 160 | 3.48 | 352 | 18 | 293 | 48.2 | 2.2 | 2930 | 10.6 |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | 8.48 | 433 | 15 | 319 | 59.3 | 1.8 | 3190 | 21.3 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, - | 160<br>160 | 7.52 | 386 | 10 | 257 | 52.8 | 1.2 | 2570 | 14.2 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, | 320<br>160 | 8.00 | 306 | 8 | 211 | 41.9 | .9 | 2110 | 3.0 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, | 160<br>320<br>160 | 12.00 | 287 | 13 | 226 | 39.3 | 1.6 | 2260 | 1.1 |
| 00, | Nothing, - - | — | — | 278 | 15 | 214 | 38.0 | 1.8 | 2140 | — |
| H, | Nitrate of Soda, -<br>Ammonite, - -<br>Muriate of Potash,<br>S.C.Dis.Rock Phos., | 125<br>100<br>200<br>350 | 13.03 | 273 | 35 | 339 | 37.4 | 4.3 | 3390 | — |
| I, | Peter Cooper's Bone,<br>Nitrate of Soda, -<br>Muriate of Potash, - | 300<br>175<br>200 | 12.98 | 374 | 10 | 183 | 51.2 | 1.2 | 1830 | 12.6 |
| K, | Dry ground Fish, -<br>Muriate of Potash, - | 510<br>200 | 13.07 | 295 | 9 | 280 | 40.4 | 1.1 | 2800 | 1.7 |

## Table 49.—*(Continued.)*

## SOIL TEST WITH FERTILIZERS ON CORN.

| No. of Plot. | Fertilizers Per Acre. | | | Yield Per Plot. (1-10 Acre.) | | | Yield Per Acre. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kind. | Weight. | Cost. | Ears. Good. | Ears. Poor. | Stover. | Shelled Corn (11 % Water.) Good. | Shelled Corn (11 % Water.) Poor. | Stover. | Gain over Nothing Plots. |
| | *By J. D. Kelsey, Madison.* | Lbs. | $ | Lbs. | Lbs. | Lbs. | Bu. | Bu. | Lbs. | Bu. |
| O, | Nothing, - - | — | — | 340 | 32 | 375 | 41.9 | 3.5 | 3750 | — |
| A, | Nitrate of Soda, - | 160 | 3.96 | 432 | 24 | 412 | 53.3 | 2.6 | 4120 | 12.4 |
| B, | Dis. Bone-black, - | 320 | 4.40 | 317 | 28 | 427 | 39.1 | 3.1 | 4270 | −1.3 |
| C, | Muriate of Potash, | 160 | 3.48 | 341 | 11 | 556 | 42.0 | 1.2 | 5560 | −.2 |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | 8.48 | 435 | 14 | 423 | 53.7 | 1.5 | 4230 | 11.7 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, | 160<br>160 | 7.52 | 464 | 14 | 453 | 57.2 | 1.5 | 4530 | 15.2 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, | 320<br>160 | 8.00 | 406 | 14 | 485 | 50.1 | 1.5 | 4850 | 8.1 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, | 160<br>320<br>160 | 12.00 | 350 | 17 | 496 | 43.2 | 1.8 | 4960 | 1.5 |
| H, | Nitrate of Soda, -<br>Ammonite, - -<br>Muriate of Potash, -<br>S.C. Dis. Rock Phos., | 125<br>100<br>200<br>350 | 13.03 | 401 | 21 | 504 | 49.4 | 2.3 | 5040 | 8.2 |
| I, | Peter Cooper's Bone,<br>Nitrate of Soda, -<br>Muriate of Potash, - | 300<br>175<br>200 | 12.98 | 419 | 15 | 465 | 50.4 | 1.6 | 4650 | 6.5 |
| K, | Dry ground Fish, -<br>Muriate of Potash, - | 510<br>200 | 13.07 | 432 | 19 | 426 | 53.3 | 2.1 | 4260 | 11.9 |
| OO, | Nothing, - - | — | — | 302 | 40 | 324 | 37.2 | 4.4 | 3240 | — |
| | *By the Station.* | | | | | | | | | |
| O, | Nothing, - - | — | — | 211 | 26 | 199 | 30.1 | 3.5 | 2388 | — |
| A, | Nitrate of Soda, - | 160 | 3.96 | 264 | 24 | 198 | 37.7 | 3.3 | 2376 | 7.5 |
| B, | Dis. Bone-black, - | 320 | 4.40 | 239 | 26 | 208 | 34.1 | 3.5 | 2496 | 4.1 |
| C, | Muriate of Potash, - | 160 | 3.48 | 260 | 27 | 259 | 37.1 | 3.7 | 3108 | 7.3 |
| OO, | Nothing, - - | — | — | 153 | 45 | 163 | 21.8 | 6.2 | 1956 | — |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | 8.48 | 267 | 20 | 198 | 38.1 | 2.7 | 2376 | 7.3 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, - | 160<br>160 | 7.52 | 320 | 14 | 273 | 45.7 | 1.9 | 2276 | 14.1 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, - | 320<br>160 | 8.00 | 322 | 16 | 326 | 46.0 | 2.2 | 3912 | 14.7 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, - | 160<br>320<br>160 | 12.00 | 399 | 10 | 332 | 56.9 | 1.3 | 3984 | 24.7 |
| OOO | Nothing, - - | — | — | 241 | 33 | 182 | 34.4 | 4.5 | 2208 | — |
| X, | Stable Manure, -<br>Dis. Bone-black, - | 12000<br>160 | 18.80 | 386 | 14 | 330 | 55.1 | 1.9 | 3960 | 23.5 |
| Y, | Stable Manure, - | 16000 | 19.20 | 378 | 20 | 338 | 54.0 | 2.7 | 4056 | 23.2 |

TABLE 49.—*(Continued.)*

SOIL TEST WITH FERTILIZERS ON CORN.

| No. of Plot. | Fertilizers Per Acre. | | | Yield Per Plot. (1-10 Acre.) | | | Yield Per Acre. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kind. | Weight. | Cost. | Ears. | | Stover. | Shelled Corn (11 % Water.) | | Stover. | Gain over Nothing Plots. |
| | | | | Good. | Poor. | | Good. | Poor. | | |
| | *By Ekonk Grange.* | Lbs. | $ | Lbs. | Lbs. | Lbs. | Bu. | Bu. | Lbs. | Bu. |
| 0, | Nothing, - - - | — | — | 189 | 22 | 165 | 19.3 | 1.9 | 1650 | — |
| A, | Nitrate of Soda, - | 160 | 3.96 | 203 | 20 | 181 | 20.7 | 1.7 | 1810 | -2.0 |
| B, | Dis. Bone-black, - | 320 | 4.40 | 198 | 29 | 172 | 20.2 | 1.6 | 1720 | -2.6 |
| C, | Muriate of Potash, - | 160 | 3.48 | 290 | 14 | 258 | 29.6 | 1.2 | 2580 | 6.4 |
| D, | Nitrate of Soda, -<br>Dis. Bone-black, - | 160<br>320 | 8.48 | 253 | 18 | 196 | 25.8 | 1.5 | 1960 | 2.9 |
| E, | Nitrate of Soda, -<br>Muriate of Potash, - | 160<br>160 | 7.52 | 271 | 16 | 256 | 27.6 | 1.3 | 2560 | 4.5 |
| F, | Dis. Bone-black, -<br>Muriate of Potash, - | 320<br>160 | 8.00 | 399 | 11 | 310 | 40.6 | .9 | 3100 | 17.1 |
| G, | Nitrate of Soda, -<br>Dis. Bone-black, -<br>Muriate of Potash, - | 160<br>320<br>160 | 12.00 | 383 | 13 | 319 | 39.1 | 1.1 | 3190 | 15.8 |
| 00, | Nothing, - - - | — | — | 204 | 30 | 189 | 20.8 | 2.6 | 1890 | — |
| H, | Ashes, - - - | 1000 | 10.00 | 310 | 16 | 258 | 33.8 | 1.3 | 2580 | 10.7 |
| I, | Nitrate of Soda, -<br>Muriate of Potash, -<br>Dis. Bone-black, - | 160<br>160<br>480 | 13.76 | 418 | 14 | 341 | 42.6 | 1.2 | 3410 | 19.4 |
| K, | Ammonite, - -<br>Muriate of Potash, -<br>Dis. Bone-black, - | 190<br>160<br>480 | 14.23 | 426 | 10 | 382 | 43.4 | .8 | 3820 | 19.8 |
| L, | Peter Cooper's Bone, -<br>Nitrate of Soda, -<br>Muriate of Potash, - | 500<br>100<br>160 | 13.02 | 391 | 14 | 322 | 39.9 | 1.2 | 3220 | 16.7 |
| M, | Nitrate of Soda, -<br>Ammonite, - -<br>Muriate of Potash, -<br>S. C. Dis. Rock Phos., | 90<br>80<br>160<br>600 | 13.05 | 432 | 14 | 370 | 44.0 | 1.2 | 3700 | 20.8 |
| 000 | Nothing, - - - | — | — | 260 | 24 | 221 | 26.5 | 2.0 | 2210 | — |

# STUDIES OF DIETARIES.

REPORTED BY W. O. ATWATER AND CHAS. D. WOODS.

Accounts of studies of dietaries of families and a boarding house, by the Station, have been given in previous reports, as follows:

1. A boarding house.*
2. A chemist's family.*
3. A jeweler's family.†
4. A blacksmith's family.†
5. A machinist's family.†
6. A mason's family.†
7. A carpenter's family.†
8. A carpenter's family.†
9. The family of the Station Agriculturist in winter.‡
10. A mason's family (the same as No. 6).‡
11. A carpenter's family (the same as No. 8).‡
12. A College students' club.‡
13. The family of the Station Agriculturist in summer.‡

Eight additional dietaries are here reported:

14. A widow's family.
15. A Swede family.
16. A College club.
17. A Divinity School club.
18. College lady students' club.
19. A Swede family (same as No. 15).
20. Three chemists.
21. A carpenter's family.

In the dietaries studies here reported upon the work was shared by Dr. H. B. Gibson, Mr. H. Monmouth Smith, Dr. R. L. Slagle, Dr. P. N. Evans, Mr. H. A. Torrey, Mr. H. M. Burr, Miss Katherine B. Camp and Miss H. M. Hall. The dietary study of a College club (No. 16) was under the especial charge of Dr. Gibson and Mr. Smith, that of a Divinity School club was largely the work of Mr. Smith. Miss Camp had the especial oversight of that of the College ladies' eating club (No. 18). The details of the study of the dietary of three chemists (No. 20) were carried out by Messrs. Smith, Slagle and Torrey.

The general plan of the investigation included an account of the amounts and composition of all food materials of nutritive value in the house at the beginning, purchased during and remaining at the end of the experiment, and of all the kitchen and table wastes. The amounts of different food materials on

* Report of this Station, 1891, pp. 90-106. † Report of this Station, 1892, pp. 135-162.
‡ Report of this Station, 1893, pp. 174-197.

hand at the beginning and received during the experiment were added; from this sum the amounts remaining at the end were subtracted. This gave the amount of each material actually used. From the amount thus obtained and the composition of each material, as shown by analysis, the amounts of the nutritive ingredients were estimated. From these were subtracted the amounts of nutrients in the waste, and thus the amounts of nutrients actually eaten were learned.

Account was kept of the meals taken by the different members of the family, and by visitors. The number of meals for one man, to which the total number actual meals taken was equivalent, was estimated upon the basis of the potential energy, as has been done in previous investigations here.* These energy equivalents, which are stated below, are somewhat arbitrary, and require revision in the light of accumulating inquiry. It has seemed best, however, to use the same figures here as in the previous reports and postpone the change until these dietaries may be summarized with others in a later publication.

*Estimated Relative Quantities of Potential Energy in Nutrients Required by Persons of Different Classes.*

| | |
|---|---|
| Man at moderate work, - - - - - - - | 10 |
| Woman at moderate work, - - - - - - - | 8 |
| Child, 15 months to 6 years old, - - - - - - | 7 |
| Child, 6 months to 2 years old, - - - - - - | 5 |
| Child, under 2 years old, - - - - - - - | 2½ |

EXPLANATION OF TABLES.

The figures in the first table of each dietary, giving the actual amounts of food and of nutrients in the food used during the dietary, are based upon the weights of the food materials as they were purchased and used; that is, they include bone and other refuse, except where specified.

The first three columns in the table contain the percentages of protein, fat and carbohydrates used in computing the amounts of those nutrients in the different food materials. In all cases where the composition was not fairly well known from previous analyses, specimens of the food materials actually used in the dietary, or specimens as nearly identical as possible, were analyzed. The cases in which special analyses were made in connection with these dietaries are indicated in the table by placing the letter *a* after the name of the material. The weights of the water-free

* See especially 17th Annual Report of the Massachusetts Bureau of Statistics of Labor, pp. 239–329.

table and kitchen wastes, and their composition, are given in the last line of the table. Exactly what is included in these wastes is explained in the foot note on page 97 of the Report of this Station for 1891.*

The last table in each dietary gives the nutrients and potential energy in food purchased, in table and kitchen wastes, and in the portion actually eaten. The estimates of animal and vegetable nutrients in the waste are computed as below described. In estimating the fuel values of the nutritive ingredients the protein and carbohydrates are assumed to contain 4.1 and the fats 9.3 calories of potential energy per gram.†

It was not practicable in the collection of the wastes to distinguish between that which came from animal and that from vegetable food. It is, however, possible to estimate with more or less accuracy how much of the nutritive materials came from the animal and how much from the vegetable foods. As there were practically no carbohydrates in any of the animal foods except milk and cheese, and but little in these, we shall not greatly err in assuming that all the waste carbohydrates came from the vegetable foods. It will also be fairly accurate to assume that there are the same proportions of protein, fat and carbohydrates in the vegetable waste as in the whole vegetable food purchased. In other words, the amount of vegetable protein and vegetable fat in the waste will bear nearly the same ratio to the total amount of vegetable protein and fat in the food purchased that the carbohydrates of the waste does to the total carbohydrates of the vegetable food. Taking the percentages of the weights of the carbohydrates in the total waste as the measure of the protein and fats in the vegetable wastes, the actual weights of protein and fat in the latter are readily calculated. Subtracting these weights of vegetable protein and fat from the total weight of these ingredients in the waste, the remainders give the amounts of animal protein and fats in the whole waste.

Table 66 summarizes the results of the twenty-one dietary studies which have been made by the Station.

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* The words refuse and waste are used somewhat indiscriminately. In general, refuse in animal food represents inedible material, although bone, tendon, etc., which are classed as refuse, may be utilized for soup. The refuse of vegetable foods, such as parings, seeds, etc., represent not only inedible material, but also more or less of edible material. The waste includes the edible portion of the food, as pieces of meat, bread, etc., which might be saved, but is actually thrown away with the refuse.

† Report of this Station, 1890, p. 174.

No. 14.

## DIETARY OF A WIDOW'S FAMILY.

The study began February 1, 1894, and continued 28 days. The members of the family and number of meals taken were as follows:

Woman, 45 to 50 years old, (assumed = .8 of one man,) 84 × .8 = 67 meals.
Girl, 16 years old, (assumed = .8 of one man,) 84 × .8 = 67 meals.
Boy, 19 years old, 84 meals.
Total equivalent to 218 meals, or 72 days for one man.

TABLE 50.

*Food Materials and Table and Kitchen Wastes in Dietary of a Widow's Family During Twenty-eight Days.*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Nutrients. Protein. | Fat. | Carbohydrates. |
| ANIMAL FOOD. *Beef.* | % | % | % | Grams. | Grams. | Grams. | Grams. |
| Steak, cooked, | 26.7 | 17.1 | — | 310 | 83 | 53 | — |
| Shoulder steak (*a*), | 16.8 | 16.5 | — | 1,445 | 243 | 238 | — |
| Round steak, no bone (*a*), | 22.1 | 6.5 | — | 650 | 144 | 42 | — |
| Shank, no bone, | 22.7 | 2.3 | — | 2,355 | 535 | 54 | — |
| Flank, no bone, | 12.0 | 59.9 | — | 2,070 | 248 | 1,240 | — |
| Total, | — | — | — | 6,830 | 1,253 | 1,627 | — |
| *Pork.* | | | | | | | |
| Chops (*a*), | 15.1 | 14.5 | — | 1,840 | 278 | 268 | — |
| Salt pork, | .9 | 82.8 | — | 1,090 | 9 | 902 | — |
| Lard, | — | 99.8 | — | 2,225 | — | 2,220 | — |
| Total, | — | — | — | 5,155 | 287 | 3,390 | — |
| *Fish, Etc.* | | | | | | | |
| Clams, without shell, | 8.6 | 1.0 | 2.0 | 2,185 | 188 | 22 | 44 |
| *Dairy Products, Etc.* | | | | | | | |
| Whole milk (*a*), | 3.3 | 4.1 | 4.2 | 8,860 | 292 | 363 | 372 |
| Skimmed milk, | 2.4 | .3 | 4.1 | 5,685 | 136 | 17 | 233 |
| Butter, | — | 85.0 | — | 2,070 | — | 1,759 | — |
| Cheese, | 28.3 | 35.5 | 1.8 | 850 | 241 | 302 | 15 |
| Total, | — | — | — | 17,465 | 669 | 2,441 | 620 |
| Eggs, | 14.9 | 10.5 | — | 1,050 | 156 | 110 | — |
| Total animal food, | — | — | — | 32,685 | 2,553 | 7,590 | 664 |

TABLE 50.—*(Continued.)*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbohydrates. |
| Vegetable Food. | % | % | % | Grams. | Grams. | Grams. | Grams. |
| Cabbage (15.5 per cent. refuse), | 1.5 | .2 | 4.6 | 5,340 | 81 | 11 | 246 |
| Onions (10 per cent. refuse), - | 1.4 | .3 | 10.1 | 2,260 | 32 | 7 | 228 |
| Potatoes (15 per cent. refuse), | 2.1 | .1 | 17.9 | 28,890 | 607 | 29 | 5,170 |
| Potatoes, cooked, - - - | 2.6 | .1 | 21.0 | 980 | 25 | 1 | 206 |
| Split peas, - - - - - | 26.3 | .9 | 61.4 | 570 | 150 | 5 | 350 |
| Beans, dried, - - - | 23.1 | 2.0 | 59.2 | 1,830 | 423 | 37 | 108 |
| Canned corn, - - - | 2.8 | 1.3 | 19.6 | 495 | 14 | 6 | 97 |
| Rice, - - - - - - | 7.4 | .4 | 79.4 | 340 | 25 | 1 | 270 |
| Apples, etc., - - - - | .3 | .4 | 15.9 | 2,480 | 7 | 9 | 394 |
| Prunes, dried, - - - | 2.2 | .5 | 66.6 | 455 | 10 | 2 | 303 |
| Oranges, - - - - - | 1.0 | .9 | 8.3 | 705 | 7 | 6 | 59 |
| Canned tomatoes, - - - | 1.0 | .2 | 3.7 | 540 | 5 | 1 | 20 |
| Wheat bread, - - - | 9.1 | 1.6 | 56.0 | 1,120 | 102 | 18 | 627 |
| Rye bread, - - - - | 8.4 | .5 | 59.7 | 1,445 | 121 | 7 | 863 |
| Cake, - - - - - - | 8.3 | 10.8 | 57.8 | 425 | 35 | 45 | 245 |
| Milk crackers, - - - | 9.3 | 13.1 | 69.2 | 1,105 | 103 | 145 | 765 |
| Pilot bread crackers, - - | 12.4 | 4.4 | 74.2 | 455 | 56 | 20 | 338 |
| Flour (*a*), - - - - - | 16.4 | 1.3 | 81.7 | 24,650 | 4,042 | 320 | 20,139 |
| Buckwheat flour, - - - | 6.9 | 1.4 | 76.1 | 470 | 32 | 6 | 358 |
| Corn meal and samp, - - | 9.2 | 3.8 | 70.6 | 1,235 | 113 | 47 | 871 |
| Oat meal, - - - - - | 14.7 | 7.1 | 68.4 | 850 | 125 | 60 | 581 |
| Extra C Sugar, - - - | — | — | 86.5 | 3,700 | — | — | 3,200 |
| Molasses, - - - - - | — | — | 72.0 | 1,790 | — | — | 1,288 |
| Total vegetable food, - - | — | — | — | 82,130 | 6,115 | 783 | 36,726 |
| Total animal and vegetable food, - - - - | — | — | — | 114815 | 8,668 | 8,373 | 37,390 |
| Table and kitchen wastes (*a*), | 14.7 | 20.9 | 52.9 | 1,656 | 243 | 346 | 876 |

TABLE 51.

*Nutrients and Potential Energy in Food Purchased, Rejected and Eaten in Dietary of a Widow's Family.*

| Food Materials. | | Nutrients. Protein. | Fat. | Carbo-hydrates. | Fuel Value. |
|---|---|---|---|---|---|
| *For Family, 28 Days.* | | Grams. | Grams. | Grams. | Calories. |
| Food purchased, | Animal, | 2,553 | 7,590 | 664 | 83,775 |
| | Vegetable, | 6,115 | 783 | 36,726 | 182,915 |
| | Total, | 8,668 | 8,373 | 37,390 | 266,690 |
| Waste, | Animal, | 100 | 328 | — | 3,460 |
| | Vegetable, | 143 | 18 | 876 | 4,345 |
| | Total, | 243 | 346 | 876 | 7,805 |
| Foods actually eaten, | Animal, | 2,453 | 7,262 | 664 | 80,315 |
| | Vegetable, | 5,972 | 765 | 35,850 | 178,570 |
| | Total, | 8,425 | 8,027 | 36,514 | 258,885 |
| *Per Man Per Day.* | | | | | |
| Food purchased, | Animal, | 35 | 104 | 9 | 1,150 |
| | Vegetable, | 84 | 11 | 503 | 2,505 |
| | Total, | 119 | 115 | 512 | 3,655 |
| Waste, | Animal, | 1 | 4 | — | 50 |
| | Vegetable, | 2 | — | 12 | 60 |
| | Total, | 3 | 4 | 12 | 110 |
| Foods actually eaten, | Animal, | 34 | 100 | 9 | 1,100 |
| | Vegetable, | 82 | 11 | 491 | 2,445 |
| | Total, | 116 | 111 | 500 | 3,545 |
| *Percentages of Total Foods Purchased.* | | | | | |
| Food purchased, | Animal, | 29.5 | 90.6 | 1.8 | 31.4 |
| | Vegetable, | 70.5 | 9.4 | 98.2 | 68.6 |
| | Total, | 100.0 | 100.0 | 100.0 | 100.0 |
| Waste, | Animal, | 1.2 | 3.9 | — | 1.3 |
| | Vegetable, | 1.7 | .2 | 2.3 | 1.6 |
| | Total, | 2.9 | 4.1 | 2.3 | 2.9 |
| Foods actually eaten, | Animal, | 28.3 | 86.7 | 1.8 | 30.1 |
| | Vegetable, | 68.8 | 9.2 | 95.9 | 67.0 |
| | Total, | 97.1 | 95.9 | 97.7 | 97.1 |

## No. 15.

## DIETARY OF A SWEDE FAMILY.

The study began February 2, 1894, and continued 28 days. The members of the family and number of meals taken were as follows:

Man, 28 years old, without steady employment, 84 meals.

Woman, 26 years old, (assumed = .8 of one man,) 84 × .8 = 67 meals.

Two girls, 3 and 5½ years old, (each assumed = .4 of one man,) 2 × 84 × .4 = 67 meals.

Child, 5 months old, (assumed = .25 of one man,) 84 × .25 = 21 meals.

Total equivalent to 239 meals, or 80 days for one man.

### Table 52.

*Food Materials and Table and Kitchen Wastes in Dietary of a Swede Family During Twenty-eight Days.*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbo-hydrates. |
| **Animal Food.** | % | % | % | Grams. | Grams. | Grams. | Grams. |
| *Beef.* | | | | | | | |
| Sirloin, no bone (*a*), - - | 19.6 | 16.1 | — | 1,115 | 219 | 179 | — |
| Shoulder, no bone (*a*), - - | 18.9 | 18.6 | — | 1,285 | 243 | 239 | — |
| Shoulder, no bone (*a*), - - | 17.3 | 16.4 | — | 1,410 | 244 | 231 | — |
| Shoulder, no bone (*a*), - - | 16.3 | 29.5 | — | 760 | 124 | 224 | — |
| Round steak, no bone (*a*), - | 21.9 | 6.4 | — | 975 | 380 | 39 | — |
| Round steak, no bone (*a*), - | 22.1 | 6.5 | — | 425 | 94 | 28 | — |
| Shank, no bone (*a*), - - | 23.3 | 5.4 | — | 1,160 | 270 | 63 | — |
| Rump, no bone (*a*), - - | 21.2 | 8.9 | — | 1,735 | 368 | 154 | — |
| Corned beef, no bone (*a*), - | 17.6 | 11.8 | — | 1,415 | 249 | 167 | — |
| Corned beef, no bone (*a*), - | 16.7 | 14.9 | — | 510 | 85 | 76 | — |
| Canned corned beef, - - | 26.7 | 17.1 | — | 735 | 196 | 126 | — |
| Total, - - - - - | — | — | — | 11,525 | 2,472 | 1,526 | — |
| Veal, no bone (*a*), - - | 19.2 | 11.6 | — | 1,360 | 261 | 158 | — |
| Frankfort sausage (*a*), - - | 33.1 | 25.9 | — | 1,035 | 343 | 268 | — |
| *Pork.* | | | | | | | |
| Chops, no bone (*a*), - - | 8.1 | 15.3 | — | 845 | 68 | 129 | — |
| Sparerib, no bone (*a*), - - | 18.9 | 25.0 | — | 1,000 | 189 | 250 | — |
| Chops, no bone (*a*), - - | 19.7 | 19.0 | — | 525 | 103 | 100 | — |
| Salt pork, - - - - - | .9 | 82.8 | — | 1,460 | 13 | 1,205 | — |
| Lard, - - - - - - | — | 99.8 | — | 1,490 | — | 1,487 | — |
| Total, - - - - - | — | — | — | 5,320 | 373 | 3,171 | — |
| Pickled herring, - - - | 20.2 | 8.8 | — | 1,190 | 240 | 105 | — |

TABLE 52.—(*Continued.*)

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbohydrates. |
| ANIMAL FOOD.—(*Con.*) *Dairy Products.* | % | % | % | Grams. | Grams. | Grams. | Grams. |
| Skimmed milk, | 3.8 | .4 | 3.5 | 28,265 | 1,074 | 113 | 989 |
| Condensed milk, | 11.8 | 10.4 | 50.1 | 2,325 | 274 | 242 | 1,165 |
| Butter, | — | 85.0 | — | 2,850 | — | 2,425 | — |
| Total, | — | — | — | 33,440 | 1,348 | 2,780 | 2,154 |
| Eggs, | 14.9 | 10.5 | — | 1,360 | 203 | 143 | — |
| Total animal food, | — | — | — | 55,230 | 5,240 | 8,151 | 2,154 |
| VEGETABLE FOOD. | | | | | | | |
| Potatoes (15 per cent. refuse), | 2.1 | .1 | 17.9 | 1,660 | 35 | 2 | 297 |
| Turnips (30 per cent. refuse), | 1.2 | .2 | 8.2 | 1,270 | 15 | 3 | 104 |
| Onions (10 per cent. refuse), | 1.4 | .3 | 10.1 | 500 | 7 | 1 | 50 |
| Rice, | 7.4 | .4 | 79.4 | 735 | 54 | 3 | 583 |
| Dried beans, | 23.1 | 2.0 | 59.2 | 1,230 | 284 | 24 | 728 |
| Canned peas (*a*), | 4.8 | .3 | 11.3 | 1,015 | 49 | 3 | 115 |
| Mince-meat preparation, | 4.0 | 2.2 | 67.4 | 695 | 28 | 15 | 468 |
| Cranberries, | .4 | .9 | 10.9 | 495 | 2 | 4 | 54 |
| Wheat flour (*a*), | 12.8 | 1.2 | 73.3 | 2,110 | 270 | 25 | 1,546 |
| Wheat flour (*a*), | 13.9 | 1.4 | 73.8 | 17,805 | 2,475 | 249 | 13,140 |
| Rye flour, | 6.7 | .8 | 78.7 | 1,390 | 93 | 11 | 1,094 |
| Oat meal (*a*), | 17.0 | 7.7 | 65.5 | 3,190 | 542 | 246 | 2,089 |
| Corn meal (*a*), | 9.1 | 1.5 | 77.1 | 1,330 | 121 | 20 | 1,025 |
| Cereline, | 11.9 | 1.7 | 74.6 | 185 | 22 | 3 | 138 |
| Rye bread, | 8.4 | .5 | 59.7 | 940 | 79 | 5 | 561 |
| Milk crackers, | 9.3 | 13.1 | 69.2 | 3,600 | 335 | 472 | 2,491 |
| Granulated sugar, | — | — | 100.0 | 10,985 | — | — | 10,985 |
| Molasses, | — | — | 72.0 | 1,700 | — | — | 1,224 |
| Total vegetable food, | — | — | — | 50,835 | 4,411 | 1,086 | 36,692 |
| Total animal and vegetable food, | — | — | — | 106065 | 9,651 | 9,237 | 38,846 |
| Table and kitchen waste (*a*), | 17.4 | 31.2 | 44.2 | 1,215 | 211 | 379 | 537 |

TABLE 53.

*Nutrients and Potential Energy in Food Purchased, Rejected and Eaten in Dietary of a Swede Family.*

| Food Materials. | | Nutrients. Protein. | Fat. | Carbo-hydrates. | Fuel Value. |
|---|---|---|---|---|---|
| *For Family, 28 Days.* | | Grams. | Grams. | Grams. | Calories. |
| Food purchased, | Animal, | 5,240 | 8,151 | 2,154 | 106,120 |
| | Vegetable, | 4,411 | 1,086 | 36,692 | 174,500 |
| | Total, | 9,651 | 9,237 | 38,846 | 280,620 |
| Waste, | Animal, | 146 | 363 | — | 3,980 |
| | Vegetable, | 65 | 16 | 537 | 2,610 |
| | Total, | 211 | 379 | 537 | 6,590 |
| Food actually eaten, | Animal, | 5,094 | 7,788 | 2,154 | 102,140 |
| | Vegetable, | 4,346 | 1,070 | 36,155 | 171,890 |
| | Total, | 9,440 | 8,858 | 38,309 | 274,030 |
| *Per Man Per Day.* | | | | | |
| Food purchased, | Animal, | 66 | 102 | 27 | 1,325 |
| | Vegetable, | 55 | 14 | 446 | 2,285 |
| | Total, | 121 | 116 | 473 | 3,610 |
| Waste, | Animal, | 2 | 4 | — | 50 |
| | Vegetable, | 1 | — | 7 | 30 |
| | Total, | 3 | 4 | 7 | 80 |
| Food actually eaten, | Animal, | 64 | 98 | 27 | 1,275 |
| | Vegetable, | 54 | 14 | 439 | 2,255 |
| | Total, | 118 | 112 | 466 | 3,530 |
| *Percentage of Total Foods Purchased.* | | | | | |
| Food purchased, | Animal, | 54.3 | 88.2 | 5.5 | 37.8 |
| | Vegetable, | 45.7 | 11.8 | 94.5 | 62.2 |
| | Total, | 100.0 | 100.0 | 100.0 | 100.0 |
| Waste, | Animal, | 1.5 | 3.9 | — | 1.4 |
| | Vegetable, | .7 | .2 | 1.4 | .9 |
| | Total, | 2.2 | 4.1 | 1.4 | 2.3 |
| Food actually eaten, | Animal, | 52.8 | 84.3 | 5.5 | 36.4 |
| | Vegetable, | 45.0 | 11.6 | 93.1 | 61.3 |
| | Total, | 97.8 | 95.9 | 98.6 | 97.7 |

## No. 16.
## DIETARY OF A COLLEGE CLUB.

The study began Feb. 7 and continued 28 days.

The club included 24 members, college students. There were in addition a colored waiter and two women (each assumed = .8 of one man). The number of meals taken were as follows: 24 students, 1,918 meals; colored waiter, 84 meals; two women, (168 × .8 =) 134 meals; fed to tramps, 8 meals. Total equivalent to 2,144 meals, or 715 days for one man.

### Table 54.

*Food Materials and Table and Kitchen Wastes in Dietary of a College Club During Twenty-Eight Days.*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbohydrates. |
| Animal Food. | % | % | % | Grams. | Grams. | Grams. | Grams. |
| *Beef.* | | | | | | | |
| Soup bones (*a*), | 17.4 | 3.9 | — | 1,600 | 278 | 62 | — |
| Sirloin steak (*a*), | 19.2 | 10.7 | — | 15,425 | 2,962 | 1,650 | — |
| Round steak (*a*), | 18.4 | 12.3 | — | 9,750 | 1,794 | 1,199 | — |
| Shoulder steak, | 17.3 | 8.8 | — | 4,990 | 863 | 439 | — |
| Rib roast (*a*), | 14.3 | 13.6 | — | 5,130 | 734 | 698 | — |
| Rib roast (*a*), | 13.3 | 24.2 | — | 6,125 | 815 | 1,482 | — |
| Rib roast, | 13.8 | 18.9 | — | 12,475 | 1,722 | 2,358 | — |
| Rump (*a*), | 20.9 | 8.7 | — | 4,535 | 948 | 395 | — |
| Rump (*a*), | 21.2 | 9.8 | — | 3,005 | 637 | 294 | — |
| Rump, | 21.1 | 9.2 | — | 13,975 | 2,949 | 1,286 | — |
| Corned beef (*a*), | 16.9 | 11.3 | — | 4,595 | 777 | 519 | — |
| Corned beef (*a*), | 16.4 | 14.6 | — | 4,765 | 781 | 696 | — |
| Corned beef, | 16.7 | 13.9 | — | 13,295 | 2,220 | 1,848 | — |
| Canned corned beef (*a*), | 20.9 | 10.1 | — | 1,130 | 236 | 114 | — |
| Dried and smoked, | 28.8 | 4.4 | — | 1,245 | 359 | 55 | — |
| Liver, | 24.2 | 13.2 | 7.9 | 6,875 | 1,664 | 908 | 543 |
| Total, | — | — | — | 108,915 | 19,739 | 14,003 | 543 |
| *Veal.* | | | | | | | |
| Chops (*a*), | 16.2 | 3.9 | — | 3,175 | 514 | 124 | — |
| Chops (*a*), | 16.7 | 5.4 | — | 3,290 | 549 | 178 | — |
| Chops, | 16.5 | 4.6 | — | 10,545 | 1,740 | 485 | — |
| Leg, no bone (*a*), | 20.8 | 7.7 | — | 8,960 | 1,864 | 690 | — |
| Miscellaneous cuts (*a*), | 14.2 | 8.5 | — | 4,765 | 677 | 405 | — |
| Miscellaneous cuts (*a*), | 12.9 | 5.5 | — | 4,765 | 615 | 262 | — |
| Miscellaneous cuts, | 13.5 | 7.0 | — | 10,350 | 1,397 | 725 | — |
| Total, | — | — | — | 45,850 | 7,356 | 2,869 | — |

TABLE 54.—*(Continued.)*

| FOOD MATERIALS. | PERCENTAGE COMPOSITION. | | | WEIGHTS USED. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbohydrates. |
| ANIMAL FOOD.—*(Con.)* | % | % | % | Grams. | Grams. | Grams. | Grams. |
| *Pork.* | | | | | | | |
| Chops (*a*), | 13.3 | 25.1 | — | 3,400 | 452 | 853 | — |
| Chops (*a*), | 14.0 | 23.3 | — | 3,175 | 445 | 740 | — |
| Chops, | 13.6 | 24.2 | — | 6,465 | 879 | 1,565 | — |
| Spare rib (*a*), | 15.7 | 20.8 | — | 6,040 | 948 | 1,256 | — |
| Spare rib (*a*), | 13.3 | 24.4 | — | 3,515 | 467 | 858 | — |
| Spare rib, | 15.0 | 22.6 | — | 6,575 | 986 | 1,485 | — |
| Bacon, | 11.8 | 62.5 | — | 9,695 | 1,144 | 6,060 | — |
| Ham, | 14.8 | 34.6 | — | 11,370 | 1,683 | 3,934 | — |
| Sausage (*a*), | 10.1 | 45.1 | 3.5 | 13,295 | 1,343 | 5,996 | 465 |
| Salt pork, | .9 | 82.8 | — | 5,385 | 48 | 4,459 | — |
| Lard, | — | 99.8 | — | 3,655 | — | 3,648 | — |
| Total, | — | — | — | 72,570 | 8,395 | 30,854 | 465 |
| Cottolene, | — | 100.0 | — | 3,730 | — | 3,730 | — |
| *Lamb.* | | | | | | | |
| Leg, | 15.0 | 15.6 | — | 12,500 | 1,875 | 1,950 | — |
| *Fish, Etc.* | | | | | | | |
| Canned salmon (*a*), | 17.2 | 2.4 | — | 6,435 | 1,107 | 154 | — |
| Dry salt cod, | 21.4 | .4 | — | 3,530 | 755 | 14 | — |
| Oysters, solids, | 6.3 | 1.6 | 4.0 | 5,445 | 343 | 87 | 218 |
| Total, | — | — | — | 15,410 | 2,205 | 255 | 218 |
| *Dairy Products.* | | | | | | | |
| Milk (*a*), | 3.6 | 4.5 | 4.1 | 323,605 | 11,650 | 14,562 | 13,268 |
| Butter, | — | 85.0 | — | 42,735 | — | 36,325 | — |
| Condensed milk, | 11.8 | 10.4 | 50.1 | 1,020 | 124 | 106 | 511 |
| Total, | — | — | — | 367,360 | 11,774 | 50,993 | 13,779 |
| Eggs, | 14.9 | 10.5 | — | 16,910 | 2,520 | 1,776 | — |
| Total animal food, | — | — | — | 643,245 | 53,864 | 106,430 | 15,005 |

TABLE 54.—*(Continued.)*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbo-hydrates. |
| VEGETABLE FOOD. | % | % | % | Grams. | Grams. | Grams. | Grams. |
| Pastry flour (*a*), | 10.9 | 1.1 | 75.0 | 40,825 | 4,450 | 449 | 30,619 |
| Bread flour (*a*), | 14.2 | 1.2 | 70.3 | 49,440 | 7,020 | 593 | 34,756 |
| Bread flour (*a*), | 14.1 | 1.2 | 74.0 | 11,510 | 1,623 | 138 | 8,517 |
| Graham flour (*a*), | 17.7 | 3.6 | 66.0 | 16,585 | 2,936 | 597 | 10,946 |
| Corn meal (*a*), | 9.8 | 1.3 | 74.2 | 4,480 | 439 | 58 | 3,324 |
| Rolled oats (*a*), | 16.1 | 7.7 | 67.7 | 21,545 | 3,469 | 1,659 | 14,586 |
| Cereline, | 9.4 | 1.0 | 78.6 | 4,165 | 392 | 42 | 3,274 |
| Rice, | 7.4 | .4 | 79.4 | 1,245 | 92 | 5 | 989 |
| Hominy, | 8.3 | .4 | 77.4 | 1,985 | 165 | 8 | 1,536 |
| Oyster crackers, | 11.3 | 4.8 | 77.5 | 5,570 | 629 | 267 | 4,317 |
| Milk crackers, | 9.3 | 13.1 | 69.2 | 21,945 | 2,041 | 2,875 | 15,186 |
| Corn starch, | — | — | 97.8 | 1,160 | — | — | 1,134 |
| Vermicelli, | 10.9 | 2.9 | 72.0 | 170 | 19 | 3 | 122 |
| Cocoa and chocolate, | 6.8 | 21.0 | 67.6 | 805 | 55 | 169 | 544 |
| Dessicated cocoanut, | 6.5 | 63.7 | 24.1 | 340 | 22 | 217 | 82 |
| Molasses and maple syrup, | — | — | 72.0 | 8,515 | — | — | 6,171 |
| Granulated sugar, | — | — | 100.0 | 73,410 | — | — | 73,410 |
| Potatoes (28 % refuse), | 2.1 | .1 | 17.9 | 19,613 | 412 | 20 | 3,511 |
| Cabbage (15 % refuse), | 1.5 | .2 | 4.6 | 13,762 | 206 | 28 | 633 |
| Turnips (30 % refuse), | 1.2 | .2 | 8.2 | 3,493 | 42 | 7 | 286 |
| Carrots (15 % refuse), | 1.1 | .4 | 8.9 | 842 | 9 | 3 | 75 |
| Onions (10 % refuse), | 1.4 | .3 | 10.1 | 981 | 14 | 3 | 99 |
| Beans, dry, | 23.1 | 2.0 | 59.2 | 8,775 | 2,027 | 176 | 5,195 |
| Apples (25 % refuse), | .3 | .4 | 15.9 | 15,405 | 46 | 62 | 2,449 |
| Oranges (flesh), | 1.0 | .9 | 8.3 | 12,670 | 127 | 114 | 1,052 |
| Prunes and raisins, | 2.2 | .5 | 66.6 | 1,160 | 26 | 6 | 773 |
| Canned corn, | 2.8 | 1.3 | 19.6 | 1,035 | 29 | 13 | 203 |
| Canned squash, | .9 | .5 | 11.8 | 5,670 | 51 | 28 | 669 |
| Canned tomatoes, | 1.0 | .2 | 3.7 | 10,915 | 109 | 22 | 404 |
| Canned peas, | 4.8 | .3 | 11.3 | 4,365 | 210 | 13 | 493 |
| Canned peaches, etc., | 1.1 | .8 | 11.4 | 17,775 | 196 | 142 | 2,026 |
| Cranberries, | .4 | .9 | 10.9 | 2,040 | 8 | 18 | 222 |
| Mince meat ("none such"), | 4.0 | 2.2 | 67.4 | 4,055 | 162 | 89 | 2,733 |
| Total vegetable food, | — | — | — | 386,251 | 27,026 | 7,824 | 230,336 |
| Total animal and vegetable food, | — | — | — | 1,029,496 | 80,890 | 114,254 | 245,341 |
| WASTE. | | | | | | | |
| Fat, | — | 100.0 | — | 10,135 | — | 10,135 | — |
| Refuse (*a*), | 23.8 | 25.1 | 43.1 | 28,090 | 6,684 | 7,050 | 12,107 |
| Total, | — | — | — | 38,225 | 6,684 | 17,185 | 12,107 |

TABLE 55.

*Nutrients and Potential Energy in Food Purchased, Rejected and Eaten in Dietary of a College Club.*

| Food Materials. | | Nutrients. | | | Fuel Value. |
|---|---|---|---|---|---|
| | | Protein. | Fat. | Carbohydrates. | |
| *For Club, 28 Days.* | | Grams. | Grams. | Grams. | Calories. |
| Food purchased, | Animal, | 53,864 | 106,430 | 15,005 | 1,272,200 |
| | Vegetable, | 27,026 | 7,824 | 230,336 | 1,227,900 |
| | Total, | 80,890 | 114,254 | 245,341 | 2,500,100 |
| Waste, | Animal, | 5,264 | 16,774 | — | 177,580 |
| | Vegetable, | 1,420 | 411 | 12,107 | 59,280 |
| | Total, | 6,684 | 17,185 | 12,107 | 236,860 |
| Food actually eaten, | Animal, | 48,600 | 89,656 | 15,005 | 1,094,620 |
| | Vegetable, | 25,606 | 7,413 | 218,229 | 1,168,620 |
| | Total, | 74,206 | 97,069 | 233,234 | 2,263,240 |
| *Per Man Per Day.* | | | | | |
| Food purchased, | Animal, | 75 | 149 | 21 | 1,780 |
| | Vegetable, | 38 | 11 | 322 | 1,720 |
| | Total, | 113 | 160 | 343 | 3,500 |
| Waste, | Animal, | 7 | 23 | — | 245 |
| | Vegetable, | 2 | 1 | 17 | 85 |
| | Total, | 9 | 24 | 17 | 330 |
| Food actually eaten, | Animal, | 68 | 126 | 21 | 1,535 |
| | Vegetable, | 36 | 10 | 305 | 1,635 |
| | Total, | 104 | 136 | 326 | 3,170 |
| *Percentages of Total Food Purchased.* | | | | | |
| Food purchased, | Animal, | 66.6 | 93.1 | 6.1 | 50.9 |
| | Vegetable, | 33.4 | 6.9 | 93.9 | 49.1 |
| | Total, | 100.0 | 100.0 | 100.0 | 100.0 |
| Waste, | Animal, | 6.5 | 14.7 | — | 7.1 |
| | Vegetable, | 1.8 | .4 | 4.9 | 2.4 |
| | Total, | 8.3 | 15.1 | 4.9 | 9.5 |
| Food actually eaten, | Animal, | 60.1 | 78.5 | 6.1 | 43.8 |
| | Vegetable, | 31.6 | 6.4 | 89.0 | 46.7 |
| | Total, | 91.7 | 84.9 | 95.1 | 90.5 |

## DIETARY No. 17.

### DIETARY OF STUDENTS IN A DIVINITY SCHOOL.

The following are results of dietary studies of a students' club in a divinity school in Connecticut. The most of the details were performed by Mr. H. Monmouth Smith, although Dr. H. B. Gibson shared in the work. The management of the club was in the hands of one of the members who acted as steward. The food was purchased under his direction. It was stored, cooked and eaten in rooms especially devoted to the use of the club.

*Duration of Experiment.*—The study was commenced on the afternoon of March 12, 1894, and continued for 10 days.

*Members of the Club and Occupation.*—The club consisted of 27 men, all of whom were studying for the ministry. The ages ranged from 22 to 38 years, and the average was 25½ years. The weights of the members ranged from 130 to 180 pounds, the average being 149 pounds.

Of the members of this club 8 had their homes in Connecticut, 14 in other States, and 3 in Canada, while 2 were from foreign countries.

Seventeen were college graduates; 13 from colleges in the United States, 2 from Canada and 2 from foreign institutions. The members, like most men attending institutions of this character, were in quite moderate circumstances; one or two, however, were from decidedly well-to-do families. There were three women employed in the club, a cook, a waitress and a kitchen maid. The price of board in the club was nearly $4.00 a week.

*Meals Eaten.*—An accurate account of all absences from the table was kept, as well as of all guests entertained. The record showed that 658 meals were served to the members and 90 to the servants. Assuming that a woman eats 0.8 as much as a man, the meals eaten by the women would equal 72 meals eaten by a man, and the total number of meals served would be 730, equivalent to three meals a day for one man for 243 days.

TABLE 56.

*Amounts and Composition of Food Materials and Amounts of Nutrients in Dietary of Divinity Students.*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | | Fuel Value. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbohydrates. | |
| ANIMAL FOOD. | % | % | % | Grams. | Grams. | Grams. | Grams | Calories. |
| *Beef.* | | | | | | | | |
| Sirloin (*a*), | 15.5 | 25.9 | — | 3,345 | 519 | 866 | — | — |
| Sirloin (*a*), | 16.9 | 16.1 | — | 6,350 | 1,073 | 1,022 | — | — |
| Sirloin (*a*), | 15.6 | 16.5 | — | 2,948 | 460 | 487 | — | — |
| Rib roast (*a*), | 13.5 | 26.2 | — | 8,080 | 1,091 | 2,117 | — | — |
| Rib roast (*a*), | 14.1 | 25.0 | — | 4,508 | 636 | 1,127 | — | — |
| Canned corn, | 26.7 | 17.1 | — | 2,948 | 787 | 504 | — | — |
| Liver (*a*), | 21.5 | 5.2 | 2.0 | 1,021 | 207 | 53 | 20 | — |
| Total, | — | — | — | 29,200 | 4,773 | 6,176 | 20 | 77,090 |
| *Veal.* | | | | | | | | |
| Leg (*a*), | 19.6 | 11.6 | — | 8,956 | 1,755 | 1,039 | — | 16,855 |
| *Pork.* | | | | | | | | |
| Chops (*a*), | 14.1 | 29.1 | — | 2,934 | 414 | 854 | — | — |
| Chops (*a*), | 13.2 | 31.1 | — | 2,920 | 386 | 908 | — | — |
| Chops (*a*), | 13.2 | 27.4 | — | 1,928 | 254 | 528 | — | — |
| Fat, salt, | .9 | 82.8 | — | 468 | 4 | 388 | — | — |
| Bacon (*a*), | 7.7 | 64.0 | — | 1,021 | 79 | 653 | — | — |
| Lard, | — | 99.8 | — | 3,515 | — | 3,508 | — | — |
| Total, | — | — | — | 12,786 | 1,137 | 6,839 | — | 68,265 |
| *Lamb.* | | | | | | | | |
| Chops, | 13.9 | 26.6 | — | 1,247 | 174 | 331 | — | — |
| Chops (*a*), | 14.8 | 23.7 | — | 2,920 | 432 | 693 | — | — |
| Chops (*a*), | 13.0 | 29.5 | — | 1,814 | 236 | 535 | — | — |
| Leg (*a*), | 15.1 | 25.3 | — | 6,010 | 908 | 1,521 | — | — |
| Fore quarter, | 18.1 | 25.8 | — | 7,187 | 1,301 | 1,854 | — | — |
| Total, | — | — | — | 19,178 | 3,051 | 4,934 | — | 58,395 |
| Turkey (*a*), | 15.5 | 24.7 | — | 9,185 | 1,424 | 2,269 | — | — |
| Turkey, | 15.5 | 24.7 | — | 7,683 | 1,191 | 1,898 | — | — |
| Total, | — | — | — | 16,868 | 2,615 | 4,167 | — | 49,475 |
| Gelatine, | 100.0 | — | — | 57 | 57 | — | — | 235 |
| *Fish.* | | | | | | | | |
| Salt cod, whole, | 16.0 | .4 | — | 3,061 | 490 | 12 | — | — |
| Shad, | 9.2 | 4.8 | — | 6,237 | 574 | 299 | — | — |
| Oysters, solids, | 6.3 | 1.6 | 4.0 | 5,329 | 336 | 85 | 213 | — |
| Mackerel, canned, | 29.9 | 19.9 | 8.7 | 369 | 110 | 73 | 32 | — |
| Sardines, canned, | 43.6 | 25.3 | 12.7 | 1,814 | 791 | 459 | 230 | — |
| Total, | — | — | — | 16,810 | 2,301 | 928 | 475 | 20,010 |

TABLE 56.—*(Continued.)*

| Food Materials. | Percentage Composition. Protein. | Fat. | Carbo-hydrates. | Weights Used. Total Food Materials. | Nutrients. Protein. | Fat. | Carbo-hydrates. | Fuel Value. |
|---|---|---|---|---|---|---|---|---|
| ANIMAL FOOD. | % | % | % | Grams. | Grams. | Grams. | Grams. | Calories. |
| *Dairy Products.* | | | | | | | | |
| Milk (*a*), | 3.6 | 4.2 | 4.2 | 172,364 | 6,205 | 7,239 | 7,239 | — |
| Butter (*a*), | 1.5 | 80.4 | — | 11,056 | 166 | 8,889 | — | — |
| Cheese, | 28.0 | 35.3 | 2.1 | 1,687 | 473 | 596 | 36 | — |
| Total, | — | — | — | 185,107 | 6,844 | 16,724 | 7,275 | 213,420 |
| Eggs, | 10.2 | 13.1 | — | 22,126 | 2,256 | 2,899 | — | 36,210 |
| Total animal food, | — | — | — | 311,088 | 24,789 | 43,706 | 7,770 | 539,955 |
| VEGETABLE FOOD. | | | | | | | | |
| Potatoes, 36.5 % waste, | 2.1 | .1 | 17.9 | 51,215 | 1,076 | 51 | 9,167 | 42,470 |
| Potatoes, sweet, 15 % waste, | 1.5 | .4 | 26.0 | 4,193 | 63 | 17 | 1,090 | 4,885 |
| Beets, 15 % waste, | 1.5 | .1 | 8.8 | 3,856 | 58 | 39 | 339 | 1,990 |
| Parsnips, 15 % waste, | 1.3 | .7 | 16.2 | 3,157 | 41 | 22 | 511 | 2,470 |
| Turnips, 30 % waste, | 1.2 | .2 | 8.2 | 715 | 9 | 1 | 59 | 290 |
| Carrots, 15 % waste, | 1.1 | .4 | 8.9 | 145 | 2 | 1 | 12 | 65 |
| Lima beans, | 7.1 | .7 | 22.0 | 3,770 | 264 | 26 | 829 | 4,725 |
| Canned corn, | 3.0 | 1.3 | 22.5 | 2,509 | 75 | 34 | 565 | 2,940 |
| Canned squash, | 1.1 | .5 | 9.9 | 5,232 | 58 | 3 | 518 | 2,390 |
| Canned tomatoes, | 1.0 | .2 | 3.3 | 2,183 | 22 | 4 | 72 | 420 |
| Apples, 25 % waste, | .3 | .4 | 15.9 | 10,985 | 33 | 44 | 1,747 | 7,705 |
| Apples, evaporated, | 1.3 | .8 | 68.3 | 751 | 10 | 6 | 513 | 2,200 |
| Raisins, | 2.7 | .7 | 71.6 | 142 | 4 | 1 | 102 | 445 |
| Currants, | 2.7 | .7 | 71.6 | 42 | 1 | — | 30 | 125 |
| Bread flour (*a*), | 14.6 | 1.3 | 73.1 | 35,039 | 5,115 | 455 | 25,613 | 130,215 |
| Pastry flour (*a*), | 10.4 | 1.3 | 75.3 | 3,856 | 400 | 50 | 2,904 | 14,010 |
| Graham flour, | 11.7 | 1.7 | 71.7 | 5,415 | 634 | 92 | 3,883 | 19,375 |
| Rolled oats, | 13.4 | 6.7 | 70.2 | 4,082 | 546 | 273 | 2,865 | 16,525 |
| Corn meal, | 9.2 | 3.8 | 70.6 | 1,545 | 142 | 59 | 1,090 | 5,600 |
| Pearl barley, | 8.4 | .7 | 78.1 | 482 | 41 | 3 | 376 | 1,740 |
| Pearl hominy, | 8.3 | .4 | 77.4 | 1,389 | 115 | 6 | 1,073 | 4,925 |
| Rice, | 7.4 | .4 | 79.4 | 312 | 23 | 1 | 248 | 1,120 |
| Tapioca, | — | — | 97.8 | 113 | — | — | 111 | 455 |
| Starch, | — | — | 97.8 | 794 | — | — | 776 | 3,180 |
| Macaroni, | 13.3 | .3 | 75.4 | 765 | 102 | 2 | 577 | 2,805 |
| Sugar, | — | — | 100.0 | 20,653 | — | — | 20,653 | 84,675 |
| Molasses, | — | — | 72.0 | 340 | — | — | 245 | 1,005 |
| Syrup, | — | — | 67.0 | 2,423 | — | — | 1,623 | 6,655 |
| Syrup, maple, | — | — | 50.0 | 1,361 | — | — | 681 | 2,790 |
| Mince meat, | 4.0 | 2.2 | 67.4 | 737 | 30 | 16 | 497 | 2,310 |
| Total vegetable food, | — | — | — | 168,201 | 8,864 | 1,206 | 78,769 | 370,505 |
| Total animal & vegetable food purchased, | — | — | — | 479,289 | 33,653 | 44,912 | 86,539 | 910,460 |
| Table & k'ch'n waste(*a*), | 20.9 | 24.1 | 48.8 | 19,257 | 4,024 | 4,651 | 9,398 | 98,280 |
| Fat, | — | 1.00 | — | 6,660 | — | 6,660 | — | 61,940 |
| Total, | — | — | — | 25,917 | 4,024 | 11,311 | 9,398 | 160,220 |

TABLE 57.

*Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of Divinity Students.*

| Food Materials. | | Nutrients. | | | Fuel Value. |
|---|---|---|---|---|---|
| | | Protein. | Fat. | Carbo-hydrates. | |
| *For Club, 10 Days.* | | Grams. | Grams. | Grams. | Calories. |
| Food purchased, - | Animal, - - | 24,789 | 43,706 | 7,770 | 539,955 |
| | Vegetable, - - | 8,864 | 1,206 | 78,769 | 370,505 |
| | Total, - - | 33,653 | 44,912 | 86,539 | 910,460 |
| Waste, - - - | Animal, - - | 2,967 | 11,167 | — | 116,015 |
| | Vegetable, - - | 1,057 | 144 | 9,398 | 44,205 |
| | Total, - - | 4,024 | 11,311 | 9,398 | 160,220 |
| Food actually eaten, - | Animal, - - | 21,822 | 32,539 | 7,770 | 423,940 |
| | Vegetable, - - | 7,807 | 1,062 | 69,371 | 326,305 |
| | Total, - - | 29,629 | 33,601 | 77,141 | 750,245 |
| *Per Man Per Day.* | | | | | |
| Food purchased, - | Animal, - - | 102.0 | 179.9 | 32.0 | 2,220 |
| | Vegetable, - - | 36.5 | 4.9 | 324.1 | 1,525 |
| | Total, - - | 138.5 | 184.8 | 356.1 | 3,745 |
| Waste, - - - | Animal, - - | 12.1 | 46.0 | — | 480 |
| | Vegetable, - - | 4.4 | .5 | 38.7 | 180 |
| | Total, - - | 16.6 | 46.5 | 38.7 | 660 |
| Food actually eaten, - | Animal, - - | 89.8 | 133.9 | 32.0 | 1,740 |
| | Vegetable, - - | 32.1 | 4.4 | 285.4 | 1,345 |
| | Total, - - | 121.9 | 138.3 | 317.4 | 3,085 |
| *Percentages of Total Food Purchased.* | | | | | |
| Food purchased, - | Animal, - - | 73.7 | 97.3 | 8.9 | 59.3 |
| | Vegetable, - - | 26.3 | 2.7 | 91.1 | 40.7 |
| | Total, - - | 100.0 | 100.0 | 100.0 | 100.0 |
| Waste, - - - | Animal, - - | 8.8 | 24.9 | — | 12.8 |
| | Vegetable, - - | 3.1 | .3 | 10.9 | 4.8 |
| | Total, - - | 11.9 | 25.2 | 10.9 | 17.6 |
| Food actually eaten, - | Animal, - - | 64.9 | 72.5 | 8.9 | 46.5 |
| | Vegetable, - - | 23.2 | 2.3 | 80.2 | 35.9 |
| | Total, - - | 88.1 | 74.8 | 89.1 | 82.4 |

No. 18.

## DIETARY OF A COLLEGE LADIES' EATING CLUB.

The study began April 13, 1894, and continued 10 days. The club included 34 members, lady students and four female servants, all over 18 years of age with one exception. 1,538 meals were taken; these were equivalent to 513 days for one woman or (assuming a woman = .8 of one man) 410 days for one man.

### Table 58.

*Food Materials and Table and Kitchen Wastes in Dietary of a Ladies' College Eating Club for Ten Days.*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbohydrates. |
| Animal Food. | % | % | % | Grams. | Grams. | Grams. | Grams. |
| *Beef.* | | | | | | | |
| Rib roast (*a*), - - - | 12.5 | 27.9 | — | 13,675 | 1,709 | 3,815 | — |
| Rib roast (*a*), - - - | 12.7 | 31.3 | — | 13,795 | 1,752 | 4,318 | — |
| Rib roast (*a*), - - - | 15.6 | 34.3 | — | 14,615 | 2,280 | 5,013 | — |
| Rib roast (*a*), - - - | 13.5 | 25.8 | — | 10,630 | 1,435 | 2,743 | — |
| Sirloin steak (*a*), - - | 15.2 | 20.4 | — | 6,745 | 1,025 | 1,376 | — |
| Sirloin steak (*a*), - - | 16.1 | 23.6 | — | 5,670 | 913 | 1,338 | — |
| Sirloin steak (*a*), - - | 15.9 | 30.4 | — | 5,385 | 856 | 1,637 | — |
| Sirloin steak (*a*), - - | 17.6 | 15.6 | — | 6,065 | 1,067 | 946 | — |
| Shin, - - - - - | 13.6 | 1.4 | — | 5,345 | 727 | 75 | — |
| Liver, - - - - - | 20.1 | 5.4 | 3.5 | 1,160 | 233 | 63 | 41 |
| Corned (*a*), - - - - | 13.9 | 28.5 | — | 14,910 | 2,072 | 4,249 | — |
| Total, - - - | — | — | — | 97,995 | 14,069 | 25,573 | 41 |
| *Veal:* | | | | | | | |
| Cutlet, - - - - - | 21.1 | 10.6 | — | 3,090 | 652 | 328 | — |
| Shank, - - - - - | 10.0 | 5.3 | — | 1,220 | 122 | 65 | — |
| Loin (*a*), - - - - | 14.0 | 13.7 | — | 8,815 | 1,234 | 1,208 | — |
| Total, - - - | — | — | — | 13,125 | 2,008 | 1,601 | — |
| *Pork.* | | | | | | | |
| Ham, - - - - - | 14.8 | 34.6 | — | 4,250 | 629 | 1,471 | — |
| Salt pork, - - - - | .9 | 82.8 | — | 1,220 | 11 | 1,010 | — |
| Total, - - - | — | — | — | 5,470 | 640 | 2,481 | — |

TABLE 58.—*(Continued.)*

| Food Materials. | Percentage Composition. Protein. | Percentage Composition. Fat. | Percentage Composition. Carbohydrates. | Weights Used. Total Food Materials. | Weights Used. Nutrients. Protein. | Weights Used. Nutrients. Fat. | Weights Used. Nutrients. Carbohydrates. |
|---|---|---|---|---|---|---|---|
| ANIMAL FOOD.—*(Con.)* | % | % | % | Grams. | Grams. | Grams. | Grams. |
| *Mutton.* | | | | | | | |
| Leg (*a*), | 15.8 | 16.1 | — | 7,770 | 1,228 | 1,251 | — |
| Leg (*a*), | 14.6 | 18.4 | — | 6,110 | 892 | 1,124 | — |
| Leg, | 15.2 | 17.3 | — | 9,525 | 1,448 | 1,648 | — |
| Chops (*a*), | 12.4 | 36.3 | — | 6,265 | 777 | 2,274 | — |
| Chops (*a*), | 12.3 | 38.2 | — | 4,605 | 566 | 1,759 | — |
| Chops, | 12.4 | 37.3 | — | 5,020 | 622 | 1,872 | — |
| Flank, | 15.4 | 44.1 | — | 2,240 | 345 | 988 | — |
| Total, | — | — | — | 41,535 | 5,878 | 10,916 | — |
| *Poultry.* | | | | | | | |
| Turkey, | 23.9 | 8.7 | — | 34,885 | 8,338 | 3,035 | — |
| *Fish, Etc.* | | | | | | | |
| Shad, | 9.2 | 4.8 | — | 2,380 | 219 | 114 | — |
| Clams, | 8.6 | 1.0 | 2.0 | 1,930 | 166 | 19 | 39 |
| Oysters, | 6.3 | 1.6 | 4.0 | 2,495 | 157 | 40 | 100 |
| Salt cod, | 21.4 | .4 | — | 2,635 | 564 | 11 | — |
| Canned salmon, | 20.1 | 15.7 | — | 1,560 | 314 | 245 | — |
| Total, | — | — | — | 11,000 | 1,420 | 429 | 139 |
| Cottolene, | — | 100.0 | — | 10,090 | — | 10,090 | — |
| Gelatine, | 82.2 | .4 | — | 510 | 419 | 2 | — |
| *Dairy Products.* | | | | | | | |
| Milk (*a*), | 3.9 | 4.8 | 4.2 | 13,665 | 533 | 656 | 574 |
| Butter (*a*), | .9 | 86.1 | — | 20,215 | 182 | 17,405 | — |
| Cheese, | 28.3 | 35.5 | 1.8 | 225 | 64 | 80 | 4 |
| Total, | — | — | — | 34,105 | 779 | 18,141 | 578 |
| Eggs, | 12.1 | 10.2 | — | 25,770 | 3,118 | 2,629 | — |
| Total animal food, | — | — | — | 274,485 | 36,669 | 74,897 | 758 |
| VEGETABLE FOOD. | | | | | | | |
| Potatoes (no refuse), | 2.1 | .1 | 17.9 | 79,655 | 1,673 | 80 | 14,258 |
| Carrots (15 % refuse), | 1.1 | .4 | 8.9 | 1,400 | 15 | 6 | 225 |
| Parsnips (20 % refuse), | 2.0 | .4 | 15.5 | 11,705 | 234 | 47 | 1,814 |
| Turnips (30 % refuse), | 1.2 | .2 | 8.2 | 4,765 | 57 | 10 | 391 |

TABLE 58.—*(Continued.)*

| Food Materials. | Percentage Composition. Protein. | Fat. | Carbohydrates. | Weight Used. Total Food Materials. | Nutrients. Protein. | Fat. | Carbohydrates. |
|---|---|---|---|---|---|---|---|
| VEGETABLE FOOD.—*Con.* | % | % | % | Grams. | Grams. | Grams. | Grams. |
| Spinach, - - - - | 2.1 | .5 | 3.1 | 9,100 | 191 | 46 | 282 |
| Cranberries, - - - - | .4 | .9 | 10.9 | 1,815 | 7 | 16 | 198 |
| Onions (10 % refuse), - | 1.4 | .3 | 10.1 | 410 | 6 | 1 | 41 |
| Cabbage (15 % refuse), - | 1.5 | .2 | 4.6 | 5,395 | 81 | 11 | 248 |
| Oranges, - - - - | 1.0 | .9 | 8.3 | 5,800 | 58 | 52 | 481 |
| Canned peas, - - - - | 4.3 | .3 | 11.4 | 2,380 | 102 | 7 | 270 |
| Canned green beans, - | 4.0 | .5 | 13.5 | 4,765 | 191 | 24 | 643 |
| Canned peaches, etc., - | 1.1 | .8 | 11.4 | 22,480 | 247 | 180 | 2,563 |
| Canned corn (*a*), - - | 2.1 | .8 | 13.6 | 6,550 | 138 | 52 | 891 |
| Canned tomatoes, - - | 1.0 | .2 | 3.7 | 10,205 | 102 | 20 | 378 |
| Tapioca, corn starch, etc., | — | — | 97.8 | 810 | — | — | 792 |
| Hominy, - - - - | 8.3 | .4 | 77.4 | 1,530 | 127 | 6 | 1,184 |
| Graham flour, - - | 11.7 | 1,7 | 71.7 | 2,805 | 328 | 48 | 2,011 |
| Wheat flour (*a*), - - | 13.4 | 1.2 | 72.4 | 76,655 | 10,272 | 920 | 55,498 |
| Entire wheat flour (*a*), - | 15.4 | 1.9 | 69.8 | 4,790 | 738 | 91 | 3,343 |
| Corn meal, - - - | 9.2 | 3.8 | 70.6 | 2,185 | 201 | 83 | 1,543 |
| Oat meal (*a*), - - - | 15.3 | 7.5 | 65.7 | 3,630 | 555 | 272 | 2,385 |
| Cracked wheat, etc., - | 11.9 | 1.7 | 74.6 | 2,075 | 247 | 35 | 1,548 |
| Macaroni, - - - | 13.5 | .4 | 75.4 | 625 | 84 | 3 | 471 |
| Rice, - - - - - | 7.4 | .4 | 79.4 | 1,420 | 105 | 6 | 1,127 |
| Lima beans, - - - - | 7.1 | .7 | 22.0 | 1,900 | 135 | 13 | 418 |
| Dried beans, - - - - | 23.[illegible] | 2.0 | 59.2 | 2,950 | 681 | 59 | 1,746 |
| Banana, pulp, - - | 1.4 | 1.4 | 29.8 | 7,640 | 107 | 107 | 2,277 |
| Pine apple, - - - - | .4 | .3 | 9.7 | 3,105 | 12 | 9 | 301 |
| Currants and raisins, - | 2.7 | .7 | 71.6 | 1,075 | 29 | 8 | 770 |
| Prunes, etc., - - - - | 2.2 | .5 | 66.5 | 5,075 | 112 | 25 | 3,380 |
| Citron, - - - - - | .4 | .6 | 72.4 | 455 | 2 | 3 | 329 |
| Dates, - - - - - | 2.2 | 5.1 | 70.4 | 905 | 20 | 46 | 637 |
| Chocolate, - - - | 6.8 | 21.0 | 67.6 | 480 | 33 | 101 | 324 |
| Crackers, - - - - | 9.3 | 13.1 | 69.2 | 11,795 | 1,097 | 1,545 | 8,162 |
| Cake, - - - - - | 8.3 | 10.8 | 57.8 | 2,620 | 217 | 283 | 1,514 |
| Bread, - - - - - | 9.1 | 1.6 | 56.0 | 6,735 | 613 | 1,078 | 3,772 |
| Sugar, granulated, - - | — | — | 100.0 | 34,105 | — | — | 34,105 |
| Molasses, etc., - - | — | — | 72.0 | 5,105 | — | — | 3,676 |
| Total vegetable food, - | — | — | — | 346,895 | 18,817 | 5,293 | 153,996 |
| Total animal and vegetable food, - - | — | — | — | 621,380 | 55,486 | 80,190 | 154,754 |
| Refuse (*a*) - - - | 24.5 | 29.5 | 38.5 | 50,490 | 12,370 | 14,894 | 19,438 |

TABLE 59.

*Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a College Ladies' Eating Club.*

| Food Materials. | | Nutrients. | | | Fuel Value. |
|---|---|---|---|---|---|
| | | Protein. | Fat. | Carbo-hydrates. | |
| *For Club, 10 Days.* | | Grams. | Grams. | Grams. | Calories. |
| Food purchased, - | Animal, - | 36,669 | 74,897 | 758 | 850,000 |
| | Vegetable, - | 18,817 | 5,293 | 153,996 | 757,800 |
| | Total, - | 55,486 | 80,190 | 154,754 | 1,607,800 |
| Waste, - - - | Animal, - | 10,809 | 13,014 | — | 165,350 |
| | Vegetable, - | 1,561 | 1,880 | 19,438 | 103,580 |
| | Total, - | 12,370 | 14,894 | 19,438 | 268,930 |
| Food actually eaten, - | Animal, - | 25,860 | 61,883 | 758 | 684,650 |
| | Vegetable, - | 17,256 | 3,413 | 134,558 | 654,220 |
| | Total, - | 43,116 | 65,296 | 135,316 | 1,338,870 |
| *Per Man Per Day.* | | | | | |
| Food purchased, - | Animal, - | 89 | 183 | 2 | 2,070 |
| | Vegetable, - | 46 | 13 | 375 | 1,850 |
| | Total, - | 135 | 196 | 377 | 3,920 |
| Waste, - - - | Animal, - | 26 | 31 | — | 400 |
| | Vegetable, - | 4 | 5 | 47 | 250 |
| | Total, - | 30 | 36 | 47 | 650 |
| Food actually eaten, - | Animal, - | 63 | 152 | 2 | 1,670 |
| | Vegetable, - | 42 | 8 | 328 | 1,600 |
| | Total, - | 105 | 160 | 330 | 3,270 |
| *Percentages of Total Food Purchased.* | | | | | |
| Food purchased, - | Animal, - | 66.1 | 93.4 | .5 | 52.9 |
| | Vegetable, - | 33.9 | 6.6 | 99.5 | 47.1 |
| | Total, - | 100.0 | 100.0 | 100.0 | 100.0 |
| Waste, - - - | Animal, - | 19.5 | 16.2 | — | 10.3 |
| | Vegetable, - | 2.8 | 2.3 | 12.6 | 6.4 |
| | Total, - | 22.3 | 18.5 | 12.6 | 16.7 |
| Food actually eaten, - | Animal, - | 46.6 | 77.2 | .5 | 42.6 |
| | Vegetable, - | 31.1 | 4.3 | 86.9 | 40.7 |
| | Total, - | 77.7 | 81.5 | 87.4 | 83.3 |

No. 19.

## DIETARY OF A SWEDE FAMILY.

The study began Oct. 1st, 1894, and lasted 7 days. The family was the same as in No. 15. The man was employed in the chemical laboratory. The meals taken were: Man, 21 meals; woman (21 × .8=) 17 meals; two girls (42 × .4 =) 17 meals; child (21 × .25=) 5 meals. Total equivalent to 60 meals or 20 days for one man.

TABLE 60.

*Food Materials and Table and Kitchen Wastes in Dietary of a Swede Family During Seven Days.*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbohydrates. |
| ANIMAL FOOD. | % | % | % | Grams. | Grams. | Grams. | Grams. |
| Round steak (a), | 19.2 | 10.2 | — | 1,710 | 328 | 174 | — |
| Bologna sausage (a), | 27.6 | 32.6 | 3.9 | 385 | 106 | 126 | 15 |
| Mutton leg (a), | 19.0 | 11.5 | — | 1,075 | 203 | 123 | — |
| Pork chops, | 14.0 | 24.6 | — | 765 | 107 | 188 | — |
| Salt pork (a), | 4.6 | 91.7 | — | 255 | 12 | 234 | — |
| Smoked ham (a), | 32.6 | 12.8 | — | 580 | 189 | 234 | — |
| Lard, | — | 99.8 | — | 255 | — | 254 | — |
| Milk (a), | 3.7 | 2.3 | 4.4 | 14,160 | 524 | 326 | 623 |
| Condensed milk, | 11.8 | 10.4 | 50.1 | 455 | 54 | 47 | 228 |
| Butter, | — | 85.0 | — | 650 | — | 553 | — |
| Eggs, | 14.9 | 10.5 | — | 1,120 | 167 | 118 | — |
| Total animal food, | — | — | — | 21,410 | 1,690 | 2,377 | 866 |
| VEGETABLE FOOD. | | | | | | | |
| Potatoes (40 % refuse), | 2.1 | .1 | 17.9 | 3,690 | 78 | 4 | 660 |
| Turnips (30 % refuse), | 1.2 | .2 | 8.2 | 466 | 6 | 9 | 38 |
| Onions (10 % refuse), | 1.4 | .3 | 10.1 | 392 | 5 | 1 | 40 |
| Flour (a), | 12.5 | 1.2 | 74.8 | 4,850 | 606 | 58 | 3,628 |
| Rye flour, | 6.7 | .8 | 78.7 | 395 | 26 | 3 | 311 |
| Wheat bread, | 9.1 | 1.6 | 56.0 | 1,430 | 130 | 23 | 801 |
| Mince meat, | 4.0 | 2.2 | 67.4 | 255 | 10 | 6 | 172 |
| Milk crackers, | 9.3 | 13.1 | 69 2 | 425 | 40 | 56 | 294 |
| Rolled oats (a), | 15.1 | 8.8 | 66.1 | 170 | 26 | 15 | 112 |
| Corn meal, | 9.2 | 3.8 | 70.6 | 225 | 21 | 9 | 159 |
| Dried beans, | 23.1 | 2.0 | 59.2 | 285 | 66 | 6 | 169 |
| Sugar, | — | — | 100.0 | 4,675 | — | — | 4,675 |
| Molasses, | — | — | 72.0 | 1,005 | — | — | 724 |
| Rice, | 7.4 | .4 | 79.4 | 370 | 27 | 1 | 294 |
| Chocolate, | 6.8 | 21.0 | 67.6 | 115 | 8 | 24 | 78 |
| Total vegetable food, | — | — | — | 18,748 | 1,049 | 215 | 12,155 |
| Total food, | — | — | — | 40,158 | 2,739 | 2,592 | 13,021 |
| Table and kitchen waste (a), | 14.4 | 21.6 | 56.2 | 532 | 77 | 115 | 299 |
| Fat from kitchen waste, | — | 100.0 | — | 13 | — | 13 | — |
| Total, | — | — | — | 545 | 77 | 128 | 299 |

TABLE 61.

*Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Swede Family.*

| Food Materials. | | Nutrients. | | | Fuel Value. |
|---|---|---|---|---|---|
| | | Protein. | Fat. | Carbo-hydrates. | |
| *For Family, 7 Days.* | | Grams. | Grams. | Grams. | Calories |
| Food purchased, | Animal, | 1,690 | 2,377 | 866 | 32,580 |
| | Vegetable, | 1,049 | 215 | 12,155 | 56,130 |
| | Total, | 2,739 | 2,592 | 13,021 | 88,710 |
| Waste, | Animal, | 51 | 123 | — | 1,350 |
| | Vegetable, | 26 | 5 | 299 | 1,380 |
| | Total, | 77 | 128 | 299 | 2,730 |
| Food actually eaten, | Animal, | 1,639 | 2,254 | 866 | 31,230 |
| | Vegetable, | 1,023 | 210 | 11,856 | 54,750 |
| | Total, | 2,662 | 2,464 | 12,722 | 85,980 |
| *Per Man Per Day.* | | | | | |
| Food purchased, | Animal, | 85 | 118 | 43 | 1,630 |
| | Vegetable, | 52 | 11 | 608 | 2,810 |
| | Total, | 137 | 129 | 651 | 4,440 |
| Waste, | Animal, | 3 | 6 | — | 70 |
| | Vegetable, | 1 | — | 15 | 70 |
| | Total, | 4 | 6 | 15 | 140 |
| Food actually eaten, | Animal, | 82 | 112 | 43 | 1,560 |
| | Vegetable, | 51 | 11 | 593 | 2,740 |
| | Total, | 133 | 123 | 636 | 4,300 |
| *Percentagess of Total Food Purchased.* | | | | | |
| Food purchased, | Animal, | 61.7 | 91.7 | 6.7 | 36.7 |
| | Vegetable, | 38.3 | 8.3 | 93.3 | 63.3 |
| | Total, | 100.0 | 100.0 | 100.0 | 100.0 |
| Waste, | Animal, | 1.9 | 4.7 | — | 1.5 |
| | Vegetable, | .9 | .2 | 2.3 | 1.6 |
| | Total, | 2.8 | 4.9 | 2.3 | 3.1 |
| Food actually eaten, | Animal, | 59.8 | 87.0 | 6.7 | 35.2 |
| | Vegetable, | 37.4 | 8.1 | 91.0 | 61.7 |
| | Total, | 97.2 | 95.1 | 97.7 | 96.9 |

No. 20.

## DIETARY OF THREE CHEMISTS.

The study began Oct. 10, 1894, and continued 10 days. The three men were 28, 26, and 23 years old, respectively. They were at regular work in the laboratory, and were at the same time pursuing other studies in chemistry. They may be regarded as having very light muscular exercise. The number of meals taken were 90, or equivalent to 30 days for one man.

TABLE 62.

*Food Materials and Table and Kitchen Wastes in Dietary of Three Chemists During Ten Days.*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbohydrates. |
| ANIMAL FOOD. | % | % | % | Grams. | Grams. | Grams. | Grams. |
| *Beef.* | | | | | | | |
| Shoulder steak (*a*), | 17.0 | 14.6 | — | 345 | 59 | 50 | — |
| Shoulder steak (*a*), | 15.4 | 7.1 | — | 480 | 74 | 34 | — |
| Shoulder steak (*a*), | 14.9 | 5.9 | — | 355 | 53 | 21 | — |
| Shoulder steak (*a*), | 16.2 | 5.6 | — | 495 | 80 | 28 | — |
| Rib roast (*a*), | 17.0 | 9.0 | — | 765 | 130 | 69 | — |
| Rib roast (*a*), | 17.1 | 8.5 | — | 1,035 | 177 | 88 | — |
| Rib roast (*a*), | 13.1 | 6.8 | — | 565 | 74 | 38 | — |
| Canned corned beef (*a*), | 28.1 | 16.4 | — | 470 | 132 | 77 | — |
| Total beef, | — | — | — | 4,510 | 779 | 405 | — |
| Veal rib (*a*), | 15.3 | 2.5 | — | 865 | 132 | 216 | — |
| Veal rib (*a*), | 12.4 | 3.4 | — | 640 | 79 | 22 | — |
| Total veal, | — | — | — | 1,505 | 211 | 238 | — |
| *Pork.* | | | | | | | |
| Smoked ham (*a*), | 19.0 | 22.3 | — | 355 | 67 | 79 | — |
| Smoked ham (*a*), | 17.0 | 14.5 | — | 270 | 46 | 39 | — |
| Smoked ham (*a*), | 17.7 | 18.5 | — | 200 | 35 | 37 | — |
| Salt pork (*a*), | 2.0 | 94.1 | — | 255 | 51 | 240 | — |
| Total pork, | — | — | — | 1,080 | 199 | 395 | — |
| Cottolene (*a*), | — | 100.0 | — | 905 | — | 905 | — |
| *Fish, etc.* | | | | | | | |
| Fresh cod steaks (*a*), | 16.9 | .5 | — | 665 | 112 | 3 | — |
| Oysters, "solids" (*a*) | 6.1 | 1.0 | 1.9 | 525 | 32 | 5 | 10 |
| *Dairy Products.* | | | | | | | |
| Milk (*a*), | 3.3 | 4.6 | 5.2 | 84,035 | 277 | 387 | 437 |
| Cream (*a*), | 3.1 | 16.8 | 3.2 | 1,490 | 46 | 250 | 48 |
| Butter (*a*), | .7 | 84.2 | — | 2,280 | 16 | 1,920 | 5 |

TABLE 62.—*(Continued.)*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | Total Food Materials. | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | | Protein. | Fat. | Carbo-hydrates. |
| ANIMAL FOOD.—*(Con.)* | % | % | % | Grams. | Grams. | Grams. | Grams. |
| Cream cheese (*a*), | 23.9 | 30.2 | 8.8 | 510 | 122 | 154 | 45 |
| Eggs (*a*), | 15.5 | 11.8 | — | 1,390 | 215 | 164 | — |
| Total, | — | — | — | 89,705 | 676 | 2,875 | 535 |
| Total animal food, | — | — | — | 98,895 | 2,009 | 4,826 | 545 |
| VEGETABLE FOOD. | | | | | | | |
| Potatoes, flesh (*a*), | 2.4 | .1 | 16.9 | 6,415 | 115 | 6 | 1,039 |
| Sweet potatoes, flesh (*a*), | .9 | .3 | 28.6 | 7,555 | 68 | 23 | 216 |
| Turnips, flesh (*a*), | 1.0 | .4 | 5.3 | 2,950 | 30 | 12 | 156 |
| Squash, flesh (*a*), | 1.2 | .8 | 10.4 | 1,760 | 21 | 14 | 183 |
| Apples, flesh, | .5 | .7 | 16.0 | 4,960 | 25 | 35 | 794 |
| Bread flour (*a*), | 13.4 | 1.1 | 74.4 | 4,565 | 612 | 50 | 3,397 |
| Pastry flour (*a*), | 11.6 | .9 | 74.5 | 1,885 | 219 | 17 | 1,404 |
| Granulated sugar, | — | — | 100. | 4,255 | — | — | 4,255 |
| Rolled oats (*a*), | 18.3 | 7.2 | 66.1 | 1,090 | 199 | 79 | 720 |
| Corn meal (*a*), | 8.8 | 1.6 | 80.3 | 765 | 67 | 122 | 614 |
| Dried beans, white (*a*), | 23.8 | 1.8 | 58.9 | 695 | 165 | 13 | 409 |
| Dessicated cocoanut (*a*), | 6.5 | 64.1 | 24.3 | 45 | 3 | 29 | 11 |
| Macaroni (*a*), | 14.4 | 1.0 | 73.1 | 395 | 57 | 4 | 289 |
| Tapioca (*a*), | .3 | .1 | 88.4 | 130 | 4 | 1 | 115 |
| Milk crackers, | 9.3 | 13.1 | 69.2 | 555 | 52 | 73 | 384 |
| Total, | — | — | — | 38,020 | 1,637 | 478 | 13,986 |
| Total animal and vegetable food, | — | — | — | 136915 | 3,646 | 5,304 | 14,531 |
| Table and kitchen waste (*a*), | 16.9 | 25.4 | 49.4 | 963 | 162 | 196 | 476 |

TABLE 63.

*Nutrients and Potential Energy in Food Purchased, Rejected and Eaten in Dietary of Three Chemists.*

| Food Materials. | | Nutrients. Protein. | Nutrients. Fat. | Nutrients. Carbo-hydrates. | Fuel Value. |
|---|---|---|---|---|---|
| *For Three Men, 10 Days.* | | Grams. | Grams. | Grams. | Calories. |
| Food purchased, | Animal, | 2,009 | 4,826 | 545 | 55,360 |
| | Vegetable, | 1,637 | 478 | 13,986 | 68,500 |
| | Total, | 3,646 | 5,304 | 14,531 | 123,860 |
| Waste, | Animal, | 106 | 180 | — | 2,110 |
| | Vegetable, | 56 | 16 | 476 | 2,340 |
| | Total, | 162 | 196 | 476 | 4,450 |
| Food actually eaten, | Animal, | 1,903 | 4,646 | 545 | 53,250 |
| | Vegetable, | 1,581 | 462 | 13,510 | 66,160 |
| | Total, | 3,484 | 5,108 | 14,055 | 119,410 |
| *Per Man Per Day.* | | | | | |
| Food purchased, | Animal, | 67 | 161 | 17 | 1,845 |
| | Vegetable, | 55 | 16 | 466 | 2,285 |
| | Total, | 122 | 177 | 483 | 4,130 |
| Waste, | Animal, | 4 | 6 | — | 70 |
| | Vegetable, | 2 | 1 | 16 | 80 |
| | Total, | 6 | 7 | 16 | 150 |
| Food actually eaten, | Animal, | 63 | 155 | 17 | 1,775 |
| | Vegetable, | 53 | 15 | 450 | 2,205 |
| | Total, | 116 | 170 | 467 | 3,980 |
| *Percentages of Total Food Purchased.* | | | | | |
| Food purchased, | Animal, | 55.1 | 91.0 | 3.8 | 44.7 |
| | Vegetable, | 44.9 | 9.0 | 96.2 | 55.3 |
| | Total, | 100.0 | 100.0 | 100.0 | 100.0 |
| Waste, | Animal, | 2.9 | 3.4 | — | 1.7 |
| | Vegetable, | 1.5 | .3 | 3.3 | 1.9 |
| | Total, | 4.4 | 3.7 | 3.3 | 3.6 |
| Food actually eaten, | Animal, | 52.2 | 87.6 | 3.8 | 43.0 |
| | Vegetable, | 43.4 | 8.7 | 92.9 | 53.4 |
| | Total, | 95.6 | 96.3 | 96.7 | 96.4 |

## No. 21.

## DIETARY OF A MECHANIC'S FAMILY.

The study began Nov. 13, 1894, and continued 10 days. The members of the family and number of meals taken were as follows:

Man, about 32 years old, 26 meals.
Woman, about 29 years old (assumed = .8 of one man), 29 × .8 = 23 meals.
Woman, about 52 years old (assumed = .8 of one man), 30 × .8 = 24 meals.
Total equivalent to 73 meals or 24 days for one man.

### Table 64.

*Food Materials and Table and Kitchen Wastes in Dietary of a Mechanic's Family During Ten Days.*

| Food Materials. | Percentage Composition. | | | Weights Used. | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Nutrients. | | |
| | Protein. | Fat. | Carbohydrates. | Total Food Materials. | Protein. | Fat. | Carbo-hydrates. |
| Animal Food. | % | % | % | Grams. | Grams. | Grams. | Grams. |
| Beef, round (*a*), - - - | 19.7 | 4.8 | — | 1,445 | 285 | 69 | — |
| Beef, round (*a*), - - - | 18.0 | 8.4 | — | 595 | 107 | 50 | — |
| Beef, porter house (*a*), - - | 11.6 | 10.2 | — | 725 | 84 | 74 | — |
| Veal, rib roast (*a*), - - | 15.5 | 8.6 | — | 1,135 | 176 | 98 | — |
| Veal, loin (*a*), - - - | 21.4 | 1.5 | — | 185 | 40 | 28 | — |
| Lard, - - - - - - | — | 99.8 | — | 255 | — | 254 | — |
| Cottolene, - - - - - | — | 100.0 | — | 285 | — | 285 | — |
| Oysters, "solids," - - | 6.3 | 1.6 | 4.0 | 905 | 57 | 14 | 36 |
| *Dairy Products, Etc.* | | | | | | | |
| Milk (*a*), - - - - - | 3.9 | 4.8 | 4.5 | 10,165 | 396 | 488 | 457 |
| Buttermilk, - - - - - | 2.4 | .3 | 4.1 | 1,077 | 26 | 3 | 44 |
| Butter (*a*), - - - - - | .7 | 85.5 | — | 1,345 | 9 | 1,150 | — |
| Eggs, - - - - - - | 14.9 | 10.5 | — | 1,275 | 190 | 134 | — |
| Total animal food, - | — | — | — | 19,392 | 1,370 | 2,647 | 537 |
| Vegetable Food. | | | | | | | |
| Potatoes (15 per cent. refuse), | 2.1 | .1 | 17.9 | 5,300 | 111 | 5 | 948 |
| Sweet potatoes (12½ % refuse), | 1.5 | .4 | 26.0 | 785 | 12 | 3 | 204 |
| Cooked squash, - - - | .9 | .5 | 11.8 | 370 | 3 | 2 | 44 |
| Apples (25 % refuse), - - | .3 | .4 | 15.9 | 7,935 | 24 | 32 | 1,262 |
| Pastry flour (*a*), - - - | 11.8 | 1.2 | 74.0 | 580 | 68 | 7 | 429 |
| Bread flour (*a*), - - - | 13.5 | 1.2 | 73.5 | 5,445 | 735 | 65 | 4,002 |
| Rolled oats (*a*), - - - | 14.6 | 7.4 | 68.0 | 130 | 19 | 10 | 88 |
| Wheat germ meal (*a*), - - | 11.4 | 2.2 | 73.7 | 385 | 44 | 8 | 284 |
| Rice, - - - - - - | 7.4 | .4 | 79.4 | 200 | 15 | 1 | 150 |
| Corn starch, etc., - - - | — | — | 97.8 | 45 | — | — | 44 |
| Granulated sugar, - - | — | — | 100.0 | 2,155 | — | — | 2,155 |
| Prunes and dates, - - | 2.2 | .5 | 66.6 | 450 | 10 | 2 | 300 |
| Celery, - - - - - | 1.6 | .8 | 6.0 | 865 | 14 | 7 | 52 |
| Bread, - - - - - - | 9.1 | 1.6 | 56.0 | 255 | 23 | 4 | 143 |
| Milk crackers, - - - | 9.3 | 13.1 | 69.2 | 325 | 30 | 43 | 225 |
| Maple syrup, - - - | 4.4 | — | 65.5 | 680 | 30 | — | 445 |
| Total vegetable food, - - | — | — | — | 25,905 | 1,138 | 189 | 10,775 |
| Total animal and vegetable food, - - - | — | — | — | 45,297 | 2,508 | 2,836 | 11,312 |
| Table and kitchen wastes (*a*), | 35.8 | 41.0 | 17.2 | 199 | 71 | 82 | 34 |
| Fat, - - - - - - | — | 100.0 | — | 115 | — | 115 | — |
| Total, - - - - | — | — | — | 314 | 71 | 197 | 34 |

TABLE 65.

*Nutrients and Potential Energy in Food Purchased, Rejected, and Eaten in Dietary of a Mechanic's Family.*

| Food Materials. | | Nutrients. Protein. | Nutrients. Fat. | Nutrients. Carbohydrates. | Fuel Value. |
|---|---|---|---|---|---|
| *For Family, 10 Days.* | | Grams. | Grams. | Grams. | Calories. |
| Food purchased, | Animal, | 1,370 | 2,647 | 537 | 32,430 |
| | Vegetable, | 1,138 | 189 | 10,775 | 50,600 |
| | Total, | 2,508 | 2,836 | 11,312 | 83,030 |
| Waste, | Animal, | 68 | 196 | — | 2,105 |
| | Vegetable, | 3 | 1 | 34 | 155 |
| | Total, | 71 | 197 | 34 | 2,260 |
| Food actually eaten, | Animal, | 1,302 | 2,451 | 537 | 30,305 |
| | Vegetable, | 1,135 | 188 | 10,741 | 50,465 |
| | Total, | 2,437 | 2,639 | 11,278 | 80,770 |
| *Per Man Per Day.* | | | | | |
| Food purchased, | Animal, | 65 | 126 | 26 | 1,545 |
| | Vegetable, | 53 | 9 | 513 | 2,410 |
| | Total, | 118 | 135 | 539 | 3,955 |
| Waste, | Animal, | 3 | 9 | — | 100 |
| | Vegetable, | — | — | 2 | 5 |
| | Total, | 3 | 9 | 2 | 105 |
| Food actually eaten, | Animal, | 62 | 117 | 26 | 1,445 |
| | Vegetable, | 53 | 9 | 511 | 2,405 |
| | Total, | 115 | 126 | 537 | 3,850 |
| *Percentages of Total Food Purchased.* | | | | | |
| Food purchased, | Animal, | 54.6 | 93.3 | 4.8 | 39.1 |
| | Vegetable, | 45.4 | 6.7 | 95.2 | 60.9 |
| | Total, | 100.0 | 100.0 | 100.0 | 100.0 |
| Waste, | Animal, | 2.7 | 6.9 | — | 2.6 |
| | Vegetable, | .1 | — | .3 | .2 |
| | Total, | 2.8 | 6.9 | .3 | 2.8 |
| Food actually eaten, | Animal, | 51.8 | 86.4 | 4.8 | 36.5 |
| | Vegetable, | 45.4 | 6.7 | 94.9 | 60.7 |
| | Total, | 97.2 | 93.1 | 99.7 | 97.2 |

TABLE 66.

*Summary of Results of Dietary Studies made by the Station. Food per Man per Day.*

| Dietaries. | Nutrients. Protein. | Fat. | Carbo-hydrates. | Fuel Value. |
|---|---|---|---|---|
| | Grams. | Grams. | Grams. | Calories. |
| 1. *Dietary of a Boarding House.** | | | | |
| Food, Purchased, | 126 | 188 | 426 | 4,010 |
| Food, Waste, | 23 | 36 | 25 | 520 |
| Food, Eaten, | 103 | 152 | 401 | 3,490 |
| 2. *Dietary of a Chemist's Family.** | | | | |
| Food purchased,‖ | 118 | 103 | 430 | 3,210 |
| 3. *Dietary of a Jeweler's Family.*† | | | | |
| Food, Purchased, | 91 | 126 | 483 | 3,530 |
| Food, Waste, | 8 | 9 | 5 | 140 |
| Food, Eaten, | 83 | 117 | 478 | 3,390 |
| 4. *Dietary of a Blacksmith's Family.*† | | | | |
| Food, Purchased, | 103 | 176 | 408 | 3,730 |
| Food, Waste, | 3 | 5 | 7 | 90 |
| Food, Eaten, | 100 | 171 | 401 | 3,640 |
| 5. *Dietary of a Machinist's Family.*† | | | | |
| Food, Purchased, | 100 | 159 | 427 | 3,640 |
| Food, Waste, | 1 | 3 | 6 | 60 |
| Food, Eaten, | 99 | 156 | 421 | 3,580 |
| *Two Dietaries of a Mason's Family.*† | | | | |
| 6. December, 1892. | | | | |
| Food, Purchased, | 107 | 153 | 391 | 3,470 |
| Food, Waste, | 3 | 5 | 16 | 120 |
| Food, Eaten, | 104 | 148 | 375 | 3,350 |
| 10. May, 1893.‡ | | | | |
| Food, Purchased, | 125 | 145 | 366 | 3,365 |
| Food, Waste, | 6 | 8 | 18 | 175 |
| Food, Eaten, | 119 | 137 | 348 | 3,190 |
| *Average of 6 and 10.* | | | | |
| Food, Purchased, | 116 | 149 | 379 | 3,420 |
| Food, Waste, | 5 | 6 | 17 | 150 |
| Food, Eaten, | 111 | 143 | 362 | 3,270 |
| 7. *Dietary of a Carpenter's Family.*† | | | | |
| Food, Purchased, | 125 | 152 | 498 | 3,970 |
| Food, Waste, | 11 | 17 | 23 | 300 |
| Food, Eaten, | 114 | 135 | 475 | 3,670 |
| *Two Dietaries of a Carpenter's Family.* | | | | |
| 8. November, 1892.† | | | | |
| Food, Purchased, | 107 | 161 | 408 | 3,610 |
| Food, Waste, | 7 | 12 | 20 | 220 |
| Food, Eaten, | 100 | 149 | 388 | 3,390 |

Table 66.—*(Continued.)*

| Dietaries. | Nutrients. Protein. | Fat. | Carbohydrates. | Fuel Value. |
|---|---|---|---|---|
| | Grams. | Grams. | Grams. | Calories. |
| 11. May, 1893.‡ | | | | |
| Food, Purchased, | 115 | 125 | 346 | 3,055 |
| Food, Waste, | 4 | 3 | 10 | 96 |
| Food, Eaten, | 111 | 122 | 336 | 2,965 |
| *Average of 8 and 11.* | | | | |
| Food, Purchased, | 111 | 144 | 377 | 3,335 |
| Food, Waste, | 6 | 8 | 15 | 150 |
| Food, Eaten, | 105 | 136 | 362 | 3,185 |
| *Two Dietaries of Station Agriculturist's Family.*‡ | | | | |
| 9. Winter, 1893. | | | | |
| Food, Purchased, | 106 | 145 | 405 | 3,450 |
| Food, Waste, | 7 | 6 | 7 | 115 |
| Food, Eaten, | 99 | 139 | 398 | 3,335 |
| 13. Summer, 1893. | | | | |
| Food, Purchased, | 133 | 150 | 475 | 3,885 |
| Food, Waste, | 4 | 5 | 3 | 85 |
| Food, Eaten, | 129 | 145 | 472 | 3,800 |
| *Average of 9 and 13.* | | | | |
| Food, Purchased, | 120 | 147 | 440 | 3,670 |
| Food, Waste, | 6 | 5 | 5 | 100 |
| Food, Eaten, | 114 | 142 | 435 | 3,570 |
| 12. *Dietary of a Student's Club.*‡ | | | | |
| Food, Purchased, | 113 | 180 | 376 | 3,680 |
| Food, Waste, | 19 | 39 | 30 | 570 |
| Food, Eaten, | 94 | 141 | 346 | 3,110 |
| 14. *Dietary of a Widow's Family.*§ | | | | |
| Food, Purchased, | 119 | 115 | 512 | 3,655 |
| Food, Waste, | 3 | 4 | 12 | 110 |
| Food, Eaten, | 116 | 111 | 500 | 3,545 |
| *Two Dietaries of a Swede Family.*§ | | | | |
| 15. March, 1894. | | | | |
| Food, Purchased, | 121 | 116 | 473 | 3,610 |
| Food, Waste, | 3 | 4 | 7 | 80 |
| Food, Eaten, | 118 | 112 | 466 | 3,530 |
| 19. November, 1894. | | | | |
| Food, Purchased, | 137 | 129 | 651 | 4,440 |
| Food, Waste, | 3 | 6 | 15 | 140 |
| Food, Eaten, | 133 | 123 | 636 | 4,300 |
| *Average of 15 and 19.* | | | | |
| Food, Purchased, | 129 | 118 | 562 | 4,030 |
| Food, Waste, | 3 | 5 | 11 | 110 |
| Food, Eaten, | 126 | 113 | 551 | 3,920 |

TABLE 66.—*(Continued.)*

| Dietaries. | Nutrients. Protein. | Fat. | Carbo-hydrates. | Fuel Value. |
|---|---|---|---|---|
| | Grams. | Grams. | Grams. | Calories. |
| 16. *Dietary of a College Club.*§ | | | | |
| Food, Purchased, | 113 | 160 | 343 | 3,500 |
| Food, Waste. | 9 | 24 | 17 | 330 |
| Food, Eaten, | 104 | 136 | 326 | 3,170 |
| 17. *Dietary of a Divinity School Club.*§ | | | | |
| Food, Purchased, | 139 | 185 | 356 | 3,745 |
| Food, Waste, | 17 | 47 | 39 | 660 |
| Food, Eaten, | 122 | 138 | 317 | 3,085 |
| 18. *Dietary of a College Ladies' Eating Club.*§ | | | | |
| Food, Purchased, | 135 | 196 | 377 | 3,920 |
| Food, Waste, | 30 | 36 | 47 | 650 |
| Food, Eaten, | 105 | 160 | 330 | 3,270 |
| 20. *Dietary of Three Chemists.*§ | | | | |
| Food, Purchased, | 122 | 177 | 483 | 4,130 |
| Food, Waste, | 6 | 7 | 16 | 150 |
| Food, Eaten, | 116 | 170 | 467 | 3,980 |
| 21. *Dietary of a Carpenter's Family.*§ | | | | |
| Food, Purchased, | 118 | 135 | 539 | 3,955 |
| Food, Waste, | 3 | 9 | 2 | 105 |
| Food, Eaten, | 115 | 126 | 537 | 3,850 |
| Food eaten, Minimum of above, | 83 | 103 | 317 | 2,965 |
| Food eaten, Maximum of above, | 133 | 171 | 636 | 4,300 |
| Food eaten, Average of above, | **110** | **138** | **421** | **3,469** |
| *Dietary Standards for Men at Moderate Work.* | | | | |
| Voit (German), | 118 | 50 | 500 | 3,060 |
| Atwater (American), | 125 | 125 | 450 | 3,520 |

* Report of this Station, 1891, pp. 90–106.
† Report of this Station, 1892, pp. 135–162.
‡ Report of this Station, 1893, pp. 174–190.
‖ There was very little waste in this dietary.
§ This Report, pp. 174–201.

# STANDARDS FOR RATIONS AND DIETARIES.

BY W. O. ATWATER.

Some twenty years ago, at the Woodstock meeting of the Connecticut State Board of Agriculture in December, 1874, it was the writer's privilege to read a paper on the "Results of Late European Experiments on the Feeding of Cattle." A year before, the same subject was presented, though in less detail, at a meeting of the Maine State Board of Agriculture. These were, so far as I am aware, the first attempts in the English language to explain the theory of cattle-feeding which had become current in Germany, and to set forth the standards for rations already more or less in vogue in that country. In a paper on "The Chemistry of Foods," read at the meeting of the Connecticut Board of Agriculture in December, 1884, a brief statement was made of the main results of inquiry up to that time regarding the food and nutrition of man, with especial reference to the chemical composition of food materials and the quantities appropriated for the nutrition of people of different classes under different circumstances. Although the standards for daily dietaries there set forth had appeared in print in English before, I am not aware that they had been explained as fully as was done even in the short, popular paper just referred to.

The purpose of citing these incidents is to call attention to the short period during which the standards for rations for domestic animals and for dietaries for man, now so widely current in the United States, have been before the English reading public. The rapidity with which they have come into notice, their very general adoption in this country by writers upon the subject, by teachers, and by experimenters, and the extent to which they have become a part of the familiar knowledge of intelligent, practical men and women is, it seems to me, not only an interesting phenomenon, but an auspicious omen also, for the progress of the higher knowledge, as applied to the arts and industries of life in the United States.

The remark was lately made in the presence of a well-known Connecticut farmer that such expressions as protein, fat and carbohydrates, nutritive ratios, and standards for daily rations, which are to-day very familiar in the columns of the papers and in the discussions in agricultural meetings, were Greek to farmers in our State twenty years ago. "Say Sanskrit," said he. "We knew then that there was such a language as Greek, but we had never heard of these things." Nowadays the papers that treat of dairying and cattle-feeding refer to protein and carbohydrates and feeding standards as familiarly as to Jerseys, silos, and cotton seed meal. Not only that, but people are becoming interested to know the composition and properties of human food. Standards for daily dietaries are being widely quoted as authoritative, and, what is even more to the point, the United States Congress has provided an appropriation to be used for investigations of the economy of the food of man, based upon the same principle as the studies that are carried out by our Experiment Stations upon the food and nutrition of domestic animals. The eagerness of a large and rapidly increasing body of people to get hold of the statistics of the composition of food and of daily rations, standards for dietaries and the like, is interesting as it is encouraging. All this, it seems to me, marks the beginning of a hygienic and economic improvement, if not reform, in our food economy.

For all this progress, wide spread, rapid, and I may add inspiring, let us be profoundly thankful. If the twenty years just passed have seen so much accomplished, what may not be hoped for in the twenty years to come?

But this subject has another side. The modern doctrine of food and nutrition as applied to the nourishment of domestic animals and man is in danger of being misapplied. Indeed, it is being misapplied and to an extent already serious. To one who may claim to be a veteran in the campaign for the advance of research and of knowledge in these directions in the United States, it may be permitted to sound a note of warning.

The evils are practically three; the failure to recognize what feeding and dietary standards are and ought to be, the setting up of incorrect standards, and the blind and thoughtless use of such standards in the calculating of rations and dietaries. I will speak of these in the inverse order, taking the last first.

### WRONG USE OF FEEDING STANDARDS.

The thing against which I wish to protest first of all is the inconsiderate use of feeding standards. To read articles which appear by the hundred, not only in the columns of the press, but even in some of our Experiment Station Reports, one would think that the science of cattle-feeding was a branch of applied mathematics, the data for calculations being found in the tables for composition of feeding stuffs, and the formulas in feeding standards. We are told, practically, with a constancy of repetition which is worse than tiresome, that for feeding a milch cow, for instance, we want per thousand pounds of live weight so and so many pounds of protein and other nutrients per day; that different feeding stuffs contain such and such percentages, that is to say, so and so many pounds per hundred of these nutrients; and that, to get a proper daily ration for a cow we must first select our food materials, then take their proportions of nutrients, and figure out quantities that fit the standard. By this calculation, which is perhaps a little abstruse to the average dairyman, but in which to-day there is no lack of mathematicians, chemists, and physiologists to help him, he may easily make his calculations; or, if he does not care to take this trouble, he may find them ready made and in the greatest abundance.

I am well aware that to say this and to put it so strongly is to expose myself to the severe charge of being the first man on this side of the Atlantic to use this method of calculating rations. It may be very true that the enthusiastic young student, fresh from studies in Europe, where this doctrine originated, was indiscreet in not emphasizing more clearly than he did that standards for rations are only approximations, and very rough ones at that; that at best they could only represent very general averages; that the variation in the composition of food stuffs of the same kind were so wide that no averages of analyses could apply to all cases; that the analyses were extremely imperfect representations of actual nutritive values; that we did not know exactly how the nutrients are used in the body; that it is impossible to lay down an accurate physiological standard for animals of any given kind; that differences, not only of species and of breed but differences of individuals of the same breed are so wide as to make an accurate physiological standard out of the question; and that even if the physiological standard were rightly determined the

feeding of domestic animals for profit involves consideration of the cost of the raw material, namely, the food; the cost of the machine and its running, the animal and its care; and the value of the product, be it growth, meat, milk or work. But he had taken the pains to talk with some practical men as well as with chemists, physiologists and experts, upon the subject, in Europe and especially in Germany. He had gathered the ideas just suggested and he did try, however imperfectly, to insist upon these cautions while attempting to explain the fundamental principles of nutrition, the composition of foods and feeding stuffs and the use of standards for rations and dietaries. And it is with a sentiment akin to pain that he peruses the statements so constantly reiterated, in so many places, by so many men, and with so little qualification; implying that there is something absolute in feeding standards and in tables of composition of feeding stuffs and that what the feeder has to do is to consult his feeding standard and his tables of composition, apply his mathematics, feed his cattle accordingly, and then hope for profit.

Analyses of feeding stuffs and feeding standards are useful, incalculably so. I venture the assertion that, aside from improved breeds, the thing which has done most to help the stock grower and the dairymen in our older States is the improved system of feeding which the use of this very doctrine has done more than anything else to bring about. The danger is in the blind, unthinking use of the theory.

### THE SETTING UP OF WRONG STANDARDS.

The formulas for rations of domestic animals most commonly quoted are those of the German experimenter, Wolff. One reason for the popularity of Wolff's formulas, and perhaps the chief, is that they are so simple and so easily quoted and followed. Another is doubtless found in the fact that they have so long been a feature of the famous German Farmers' Almanac *(Mentzel und v. Lengerke's Landwirtschaftlicher Kalender)*, which in that country is much more common among farmers than the Bible and, it is to be feared, much more consulted by them. The less definite and more conservative formulas and tables of composition of feeding stuffs of Julius Kühn* are more generally

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*See Kühn's discussion of the subject of feeding standards in Experiment Station Record, volume IV., page 11.

accepted by experts in Germany than those of Wolff. Kühn urges the unwisdom of setting up standards as in any wise absolute, and calls especial attention to the difficulties in the way of assuming the composition of feeding stuffs from averages of analyses. He insists upon the great values of feeding standards and of their use in connection with the estimates of composition of feeding stuffs, but urges with emphasis the necessity of studying the individual animal and fitting the food to the observed needs rather than to any arbitrary standard. Wolff, of course, assents to these principles in a general way, and would, I am sure, protest emphatically against considering either his formulas or those of Kühn, or any others, as more than rough approximations and averages.

The following is from comments by the writer upon Prof. Kühn's article above referred to:

"Prof. Kühn calls attention to several difficulties in the way of prescribing definite feeding standards for different classes of animals which are fed for different purposes. They have to do with the animals, the feeding stuffs, and the commercial value of the feeding stuffs and the products.

"In the first place different animals of the same class differ greatly in their capacity for utilizing food, and even the same animal may require different rations under different conditions. Thus different breeds of milch cows and different cows of the same breed may vary widely with respect to the amounts of food which they can most advantageously utilize. The amount appropriate for 1,000 pounds live weight may be much greater with a small cow than with a large one. It varies with the bodily condition of the animal, whether lean or fat, and with the amount of the milk yield. The quantity of food needed depends also upon whether, as the milk falls off toward the end of the period of lactation, the cow is to be fattened for the butcher or is to be used again for breeding and milking. In brief, it is impossible to lay down hard and fast rules for quantities of food or quantities of nutrients, or for nutritive ratios to apply indiscriminately to different animals under different conditions.

"Again, different specimens of any kind of feeding stuff may vary widely in chemical composition so that the figures for average composition may be very far from the truth in a given case. The coefficients of digestibility are likewise variable. And even if the quantities of actually digestible nutrients in any given instance,

as determined by either natural or artificial digestion, should be taken as the basis of the calculation, they might be very far from expressing the nutritive value of the materials as they are actually utilized by the animal, because of the defects in our present methods of analysis and of classification of the nutrients.

"Finally, economical feeding is not simply a matter of fitting the nutrients of the food to the physiological demands, but of adjusting the kinds and quantities of feeding stuffs to their cost and to the amount and market value of the product.

"Prof. Kühn's conclusion is that to calculate rations upon a basis of the feeding standards and the average composition of the feeding stuffs, is irrational and may be very unprofitable. He would, however, by no means give up either standards or tables of composition. As regards the quantities of nutrients to be fed, he would take into consideration the individual needs of each animal and make the quantities of total food and of the several nutrients such as will best fit the special demands of the animal for sustenance and production. In calculating the amounts of feeding stuffs to be used he would not simply use the average figures, but would consider the ranges of variation and the composition of the particular materials to be fed. The ideal method would be to analyze the feeding stuffs in each case, if this were practicable, but it usually is not. But along with the chemistry and physiology of the subject, the skill of the experienced practical feeder is absolutely essential. For the method of 'individual feeding' which Prof. Kühn recommends he gives suggestions of no little interest.

"One matter which Prof. Kühn rightly insists upon is the distinction between the digestible protein, *i. e.*, total digestible nitrogenous substances and the digestible actual albuminoids. He also urges with justice that the ether extract of the coarse fodders has a much lower feeding value than that of the concentrated fodders like oil cakes and meals, which consist mostly of the true fats. He insists with like good reason that what we call non-nitrogenous extract represents a great variety of materials unknown or of doubtful value.

"Chemists clearly apprehend the difficulty with their analysis as measures of the nutritive value of feeding stuffs, but the experimenters and writers have not always appreciated the full import of the differences in individuality of animals, nor has the importance of taking into account the condition of the

individual animal been generally realized. We have learned that there is very little use in preparing formulas for fertilizers for a given plant to be used on different soils. The reason is that soils vary so widely in chemical and physical characters. We are gradually coming to understand that the differences between individual animals of the same kind if not as large as those between different soils, are nevertheless much greater than we formerly supposed. This is a fact which must be taken into account both in our experimenting and in our practical feeding.

"One point which Prof. Kühn dwells upon is of especial interest. It is that in the feeding of milch cows the rations should be fitted to the production expected. Instead of a standard giving certain amounts of nutrients per thousand pounds of live weight, he proposes to use a basal ration, which will be a little more than a maintenance ration, and to add to this quantities of nutrients proportionate to the wants of each animal and the production expected.

"Feeding standards and tables of composition and digestibility are invaluable helps to economical feeding. There is every reason to believe that they will be made more and more useful as experimental inquiry brings us more and more exact information. But they are only helps. They are to be regarded as indications rather than rules. They can not take the place of the skill of the experienced practical feeder. In his treatise on cattle feeding, to which Prof. Kühn refers, and which ought to be better known than it is on this side of the Atlantic, the principle is expressed in the German adage, which is taken as the motto of the book: '*Das Auge des Herrn mästet sein Vieh*' (the eye of the master fattens his stock)."

Of late an attempt has been made in the United States to elaborate a feeding standard for milch cows.* This formula differs from those of Wolff and Kühn, mainly in providing less protein and more fats and carbohydrates. In other words, the nutritive ratio is much wider than in the formulas of Wolff and Kühn. A table comparing several different so-called "standard rations" may be found on page 46 of the present Report.

It may be that in one case Wolff's formula will be the best and in another the so-called "American standard ration," proposed by Prof. Woll, will be the best; that is to say, the most profitable

*See Woll; Bulletins of Wisconsin Experiment Station, No. 33 and No. 38.

for the feeder. But it is extremely probable that in the great majority of cases something different from either will be really most advisable, and wherever either one of these formulas is not the most advantageous, it is the wrong one. Doubtless it will be better for any given farmer to follow almost any of the proposed formulas rather than to let his feeding be entirely haphazard. A wrong formula may be a great deal better than none. Feeding towards Wolff's formulas has unquestionably been of immense advantage. The point I wish to urge is, that the right formula is the one that fits the individual case, and that the cases in which any given formula, be it that of Wolff, or of Kühn, or of Woll, is actually the best, are the exceptions rather than the rule.

### THE PROPER SIGNIFICANCE OF FEEDING STANDARDS AND FORMULAS.

This brings us to the kernel of the whole subject. What is a feeding standard? To answer this we must first of all avoid a confusion of terms which has become common. We must distinguish between three different kinds of standards, or rather, since the word standard cannot be applied with equal propriety to all, we must distinguish between three different kinds of formulas which may be used to express quantities and proportions of nutrients for feeding. These may be designated as the physiological standard, the formula for profitable feeding, and the formula which expresses the actual practice of feeders.

### PHYSIOLOGICAL STANDARDS.

The physiological standards would express the proportions of the different nutrients, protein, fats and carbohydrates which best fit the demands of the animal for the particular kind of product demanded of it, whether that product is growth, as in the case of young animals; or meat, as in the fattening of cattle, sheep and swine; or milk, with milch cows; or work, as with horses and oxen. In all of these cases a certain amount of nutrients is required for maintenance and a certain additional amount for production. The functions of the several classes of nutrients in meeting the demands for maintenance and production have been more or less definitely shown by feeding experiments, and we have to-day, as the result of a great deal of experimenting, somewhat of an idea of the relations between the physiological demands of an animal of a given class and fed for a given purpose

and of the quantities of nutrients needed to supply it. But, unfortunately, our knowledge in all these respects is still deficient, and furthermore the differences of individual animals of the same breed, to say nothing of the differences between animals of different breeds and species, are so wide that with the most perfect knowledge of the laws of nutrition it will hardly be possible to set up accurate physiological standards for large classes of animals. There is, however, the best ground to expect that a reasonable amount of experimenting of the right kind will bring us satisfactory information in this respect.

### EXPERIMENTS NEEDED FOR PHYSIOLOGICAL STANDARDS.

The experimental inquiry needs to be of two kinds; accurate experiments in metabolism, and practical feeding trials. For the first it will be essential to take account of the income and outgo of the body of the animal, as expressed, not simply in terms of food and drink on one hand and of excreta, solid, liquid and gaseous on the other; but also in terms of chemical compounds and especially of chemical elements of the income and outgo. These will give the data for the metabolism of matter in the body. For the most desirable results, however, it will be necessary to go a step farther and take an account of the income and outgo of energy. The income of energy will be the potential energy of the food; the outgo of energy will be the potential energy of the unconsumed food, *i. e.*, that of the solid and liquid excreta, and the kinetic energy manifested in the heat diffused from the body and in the mechanical power of the muscular work performed.* In other words, we have to study the metabolism of energy as well as of matter.

Experimenting of this kind is very costly. It requires elaborate apparatus, the most skillful assistants, and very long time. The respiration calorimeter which is being elaborated at Wesleyan University in connection with the work of this Station, is intended for inquiries of this especial kind. Of course it is not necessary that a respiration calorimeter or even a respiration apparatus shall be used in all experimenting in metabolism. Much can be learned from feeding trials in which the income and outgo of only a single chemical element as nitrogen is determined. But the respiration apparatus, and especially the respiration calorimeter, must be looked to for the most accurate and decisive results.

* For detailed discussion of this particular subject see Bulletin No. 21 of the Office of Experiment Stations of the U. S. Department of Agriculture, entitled "Methods and Results of Investigations on the Chemistry and Economy of Food."

Another kind of experimenting and one which though its chief usefulness will be of a purely practical sort, will also bring results of physiological value, consists in feeding trials such as may be conducted in any well equipped experiment station in connection with a chemical laboratory. If, for instance, the subject be the effect of fodder upon milk production, rations differing in amount and composition may be fed and the amount and composition of milk determined. The difficulty with these experiments is that there are numerous other factors besides the food which affect the milk production and not all of these factors can be accurately estimated. But there is one way by which such experiments can be made very effective and useful. That is, duplication. One station alone cannot well do enough to settle any specific question, but by coöperation between different experiment stations a great deal could be accomplished. To make this coöperation successful it would be necessary to select narrow and specific questions, to decide upon a uniform plan, to use as many animals in each case as practicable and to make a large number of experiments in a number of different places. There is very little question that this would be the most economical and useful way to work. The dairy trials at the World's Fair brought results some of which were reasonably definite. In consequence they are of very great practical value. What gives them definiteness and value is that a large number of cows were used. It is not necessary that all the cows be in one place, but the "might of average figures" which can be almost said to "increase as the square of the number" is what makes the results reliable.

The series of coöperative experiments which have been conducted during the past twenty years in Germany and Denmark are a most valuable illustration of the usefulness of one way in which extensive feeding trials may be made useful.*

Both these kinds of experimenting are needed to give us a real physiological feeding standard, and when we get that standard we shall doubtless find that it is after all indefinite, that it varies with the animal as well as with the conditions of feeding; in other words, it will be at best only an average estimate and not an unvarying formula.

### FORMULAS FOR PROFITABLE FEEDING.

But the practical feeder feeds for profit, and the ration which will produce the largest amount of growth, or of total flesh or of

* See Experiment Station Record, Vol. III., pp. 507, 557, and Vol. VI., p. 585.

lean or fat meat, or the largest amount of milk or butter-fat or enable the animal to do the largest amount of work from a given quantity of nutrients, is not always or generally the one which will bring the most profit to the feeder. In other words, the physiological standard may not be the most profitable formula for feeding. The factors of profit are numerous. One of the chief is the physiological action of the nutrients, but the cost of the food and the value of the product have to be taken into account. It may be to the feeder's advantage to use a wide ration when a narrow one would give more yield for less raw material. There is a very wide difference in respect to the width of ration between the physiological standards as we now understand them and the actual feeding practice of most American farmers, but it would be as wrong to advise them to conform exactly to the physiological standard as it would be to take the average of the practice of successful feeders, for either a physiological standard or a formula for profitable feeding.

To find the formulas for feeding profitably two kinds of observation and experimenting are especially needed. The first and simplest consists in accurate observation of the actual practice of feeders and comparison of their methods of feeding with the product. This is being done by the Storrs Station with results as described in the present and previous Reports. The results thus far obtained are few and in no way remarkable, but they do represent the beginning of an inquiry which, if carried out for a series of years and with a wider and wider range of animals, breeds and methods of feeding and with such constant improvement of method as experience suggests, cannot fail to bring useful results. The value of these results will be materially increased if opportunity is taken, after observations have been made, to test the effect of changes in the feeding upon the product, as has been done in a small number of experiments detailed in the Reports referred to. We do not claim at all that the plan adopted by this Station is the best. What I do urge, and that with emphasis, is that the principle is a good one, that as the number of observations and experiments increase the value of the results will increase in still greater ratio; and that it is eminently desirable that a number of Stations should unite in work of this kind. Not only is it useful for learning the actual feeding practice of farmers and for working toward profitable feeding formulas, but it is preëminently valuable as a means of

education to the farmer. When a series of accurate experiments is carried on with a man's own cows, in his own barn, and he shares in the work, sees how it is done, follows the details and studies the results, he gets a kind of knowledge which he could not get in any other way. His neighbors will see the experiments done and talk them over with him and with each other and will be likewise benefited, and when the results are published and read, farmers who have not seen the experiments read about them and realize that they come from a union of science with practice; that they represent what their brother farmers have done with the aid of the Station as well as what the Station has done with the aid of the farmer. They study the details, they reflect upon them, they criticise them, and sometimes with a wisdom and acuteness which is most valuable to the Station experimenters; and, what is best of all, they use the results to the advantage of brain as well as purse.

But while the deducing of formulas for profit may be helped by this kind of experimental observation, the most useful information will come from coöperative experiments of a more thorough sort such as the Stations can best carry out with their own herds and near their own laboratories.

And let me repeat that profit is a matter of cost of raw material and manufacture and value of product and that all of these factors are extremely variable. A profitable formula for one plan or time may be very unprofitable for another. A fixed formula for profit is utterly irrational.

In framing his standards for rations for domestic animals Wolff apparently had what I have here designated as physiological standards chiefly in mind, although he did not make the distinction I have insisted upon and he did keep in view the profit to be gained from feeding. Such at any rate is the impression which I think one would gain from a study of Wolff's writings at the time, and especially his statement of the considerations which led to his standards. The standards were printed in the Farmers' Calendar above referred to for 1864, and are there explained. Wolff's later discussions of the subject in his *Landwirtschaftliche Fütterungslehre* and *Ernährung der landwirtschaftlichen Nutzthiere* seem to me to imply the same view on his part. Kühn lays no less stress upon the physiological aspects of the question, but being a man of larger practical experience as a feeder, he emphasizes more than Wolff does the other conditions

which decide the profit of feeding. Both, however, make accurate experiment the principal basis of their calculations.

### THE FEEDING PRACTICE OF FARMERS.

In the tabular statement on page 46 may be found results of the averages of 23 observations of methods of feeding actually practiced by dairymen in Connecticut, to which reference has just been made. The observations were made by representatives of the Station who visited each farm, and with the aid of the owner of the cows measured and weighed the food, took samples for analysis, and measured the milk and tested the quantities of fat by the Babcock method. The periods of observation were either five or twelve days each. Such observations, of course, leave much to be desired, but still the results do, without doubt, give at least a reasonably accurate idea of the actual usage of these feeders at the time when the observations were made. They doubtless diverge more or less in each case from the actual practice of feeding the herd for the season. But by repeating these observations from year to year on the same farms and on different farms, we shall gradually get more and more exact information as to how Connecticut farmers actually feed their cows, how much milk they get, and how much butter-fat it contains. Such observations collated and averaged will lead toward formulas for the actual practice of American feeders.

Another method for learning the practice of feeders has been adopted by other experiment stations and especially by two, the New York State, and the Wisconsin Station. The results of the observations by the Wisconsin Station are summarized on page 46 of the present Report, and on pages 94 to 101 of the Report of this Station for 1893. They may be found in detail in the Bulletin of the Wisconsin Station already cited. Messrs. Woods and Phelps have commented upon them in the present Report. They have also been referred to in the Experiment Station Record, Vol. VI., pages 350–352. It is not needful that I should add anything to the comments there made. The thing to be insisted upon here is that even if the average of the feeding practices of a larger or smaller number of feeders were made up from accurate observations it would be a mere chance if it were a correct formula for profit for any one of them, and that it would be still less apt to be the best formula for profitable feeding for other feeders under other conditions. The average of an indefinite number of

inaccurate observations of practices which is more or less erroneous, cannot represent the actual average practice and is still farther from indicating what is most profitable in any given case.

The editorial comments in the Experiment Station Record above referred to include the following opposite statements:

"The collection of statistics on the practice of feeding may be suggestive and useful in its way, but the error should not be made of supposing that a standard can be worked out in this manner. Thorough systematic feeding experiments by scientific experts alone can furnish the proper basis for American feeding standards. The experiments should be made in different parts of the country and continue through a number of years. They should be planned on a system which will make the results properly comparable, and the records should be accurately kept. Summaries of data obtained in this way and of the available data which we have now, would be fairly entitled to be called feeding standards. These standards would have a real value because they would be founded on scientific work and deductions. The closeness with which they would be followed by farmers in different parts of the country would, of course, depend on a number of variable conditions, as must be the case with any standard. With the further accumulation of feeding experiments, the standards would probably have to be somewhat modified and perfected."

### THE PLACE OF THE EXPERIMENTER AND THE PRACTICAL FEEDER.

Unquestionably the experience of practical feeders, and especially the experience of the most successful ones, is of the highest value. It is with the aid of such men that the doctrine of successful cattle feeding will be best worked out. The place of the chemist and physiologist is rather to explain the theory than to lay down rules for the practice of feeding. In developing his theory he will be most successful if he does as the most successful teachers, like Liebig, Henneberg, Kühn and Wolff in Germany, and Lawes and Gilbert in England, have done, namely, to make as accurate experiments and observations as possible and collate and explain their results as accurately and as simply as he can.

### STANDARDS FOR DIETARIES.

In framing the standards for daily dietaries for human beings the same physiological principles apply as in the standards for rations for domestic animals.

But by as much as men and women are of more consequence than the animals subdued to their service, by so much is it more essential that the physiological demands should be chiefly considered in the arrangement of their dietaries. And it must be remembered that we are not able to say to-day with any degree of exactness just what is the measure of these physiological demands. Certain formulas have, indeed, been proposed for dietaries of men, women and children. I have ventured to discuss them in other places,* and will only say here that there seems to me to be the danger of their misuse. The danger is the same as in the case of standards for rations for domestic animals, namely, that of regarding them in the light of statistics and recipes to be blindly followed.

## IN CONCLUSION.

In view of the interest in the economy of food for man which has lately manifested itself and is growing so rapidly, it seems to me proper to lay especial emphasis upon the fact that we have no dietary standards based upon at all satisfactory physiological data. The ones most commonly current are those of Voit and his school in Germany. In compiling these the results of the few accurate experiments available at the time were employed, but the chief stress was laid upon the observations of the quantities of food consumed, in Germany and especially in Bavaria, by persons whose conditions of life were such as to lead Voit and his followers to assume that their nourishment was normal. It is clear, however, that the eating habits of these people and of those with whom the more accurate experiments were made, and who also lived in Germany, were decided largely by their conditions. If the same observations and experiments had been made in Connecticut instead of Bavaria, it seems reasonably certain that the quantities of food consumed would have been much larger and the standards for dietaries based upon them would have been correspondingly larger than those of Voit and his school. It would be an evident mistake to accept these German standards as valid for general application. Indeed, there seems to me every reason to assume that they represent a scale of living decidedly lower than is desirable.

* See Report of Storrs Station, 1881, pages 144–161; and Bulletin No. 21 of the Office of Experiment Stations of the U. S. Department of Agriculture, on "Methods and Results of Investigation of the Chemistry and Economy of Food," pages 141–225.

SIMPLIFYING FORMULAS FOR RATIONS AND DIETARIES.

In concluding I venture to urge the desirability of simpler forms than have hitherto been current. Experimental science has brought us to the point where we may safely say that the uses of food are principally two: (1) To form the material of the body and repair its wastes; (2) to yield heat to keep the body warm and muscular and other power for the work which it has to do. In forming the tissues and fluids of the body the food serves for building and repair. In yielding heat and power it serves as fuel.

The different nutrients of the food serve the body in different ways. The principal tissue formers are the protein compounds, especially the albuminoids. These make the "flesh," and thus build up and repair the nitrogenous materials as the muscles and tendons. They also supply the albuminoids of blood, milk and other fluids. The chief fuel ingredients of the food are the carbohydrates and fat. These are either consumed in the body when the food is eaten or they are stored as fat to be used as occasion demands. The protein compounds can also serve as fuel. The carbohydrates and fats both serve for fat formation in the body. The protein, fats and carbohydrates in serving as fuel appear to replace one another in proportion to their potential energy or heats of combustion. While it is certain that the carbohydrates are transformed into fats, it is not definitely settled that in their capacity for forming the fat of the body or of the milk they stand in the same ratio to the fats of the food as does their potential energy to that of the fats. But it is reasonably probable, if not certain, that in their service for yielding heat and muscular power the value of the carbohydrates and fats is proportional to their potential energy.

It follows from this that for the ordinary purposes of nutrition the two principal factors of the food to be considered are the protein and the potential energy. To put it in another way, when the farmer feeds his stock he needs to use such kinds and amounts of food as will supply his animals the proper amounts of tissue formers and fuel values. It will be much simpler to explain the matter to him in this way than to go into the full details regarding protein, fats, carbohydrates, nitrogen-free extracts and the like. We may likewise express the formulas for rations and dietaries in terms of protein and energy or tissue

formers and fuel value. This I have attempted to do in other places.* It is done also in the pages of the present Report.

With regard to this whole matter there are two things to be especially remembered:

The first is that our tables of composition of foods and feeding stuffs and our formulas for rations and dietaries are only general indications. They are not maps, but guide posts. They are not recipes, but simply attempts to epitomize general principles. To use them rightly the principles must be understood, and in their application they must be fitted to the demands of individual cases.

The other is the need of research. A vast deal of time and thought and labor and money has been used, in this country and Europe, during the past fifty and especially the past thirty years, in attempting to learn the laws of nutrition of animals and man. The results of all this work are magnificent, and yet they are only preliminary. The time has come when three things are needed. These are: First, the collating of the results of inquiry and making them available to experimenters, teachers, students, writers, and the intelligent public; second, the systematizing of our so-called practical experimenting so that the work may be made coöperative, the results comparable, and the product more valuable; third, the developing of abstract inquiry.

This last, the abstract research, is the most difficult thing of all to accomplish. On that account, perhaps, it is the thing toward which we should strive most earnestly. What is wanted is the study of the application of the laws of the conservation of matter and the conservation of energy to the living organism, in order to discover more exactly the laws of nutrition; and the study of the chemistry and physiology of the materials used for foods and feeding stuffs, in order to learn more accurately their nutritive values.

To the former of these problems the Storrs Station is addressing a not inconsiderable part of its attention. Fortunately the United States Department of Agriculture is promoting the same inquiry. The respiration and bomb calorimeters, to which reference has been made on another page of the present Report, represent efforts in this direction.

* See Report of the Storrs Experiment Station for 1891, pp. 160 and 161, and Bulletin No. 21 of the U. S. Department of Agriculture on "Methods and Results of Investigations on the Chemistry and Economy of Food," pp. 200–213.

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